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JANUARY 20, 1975

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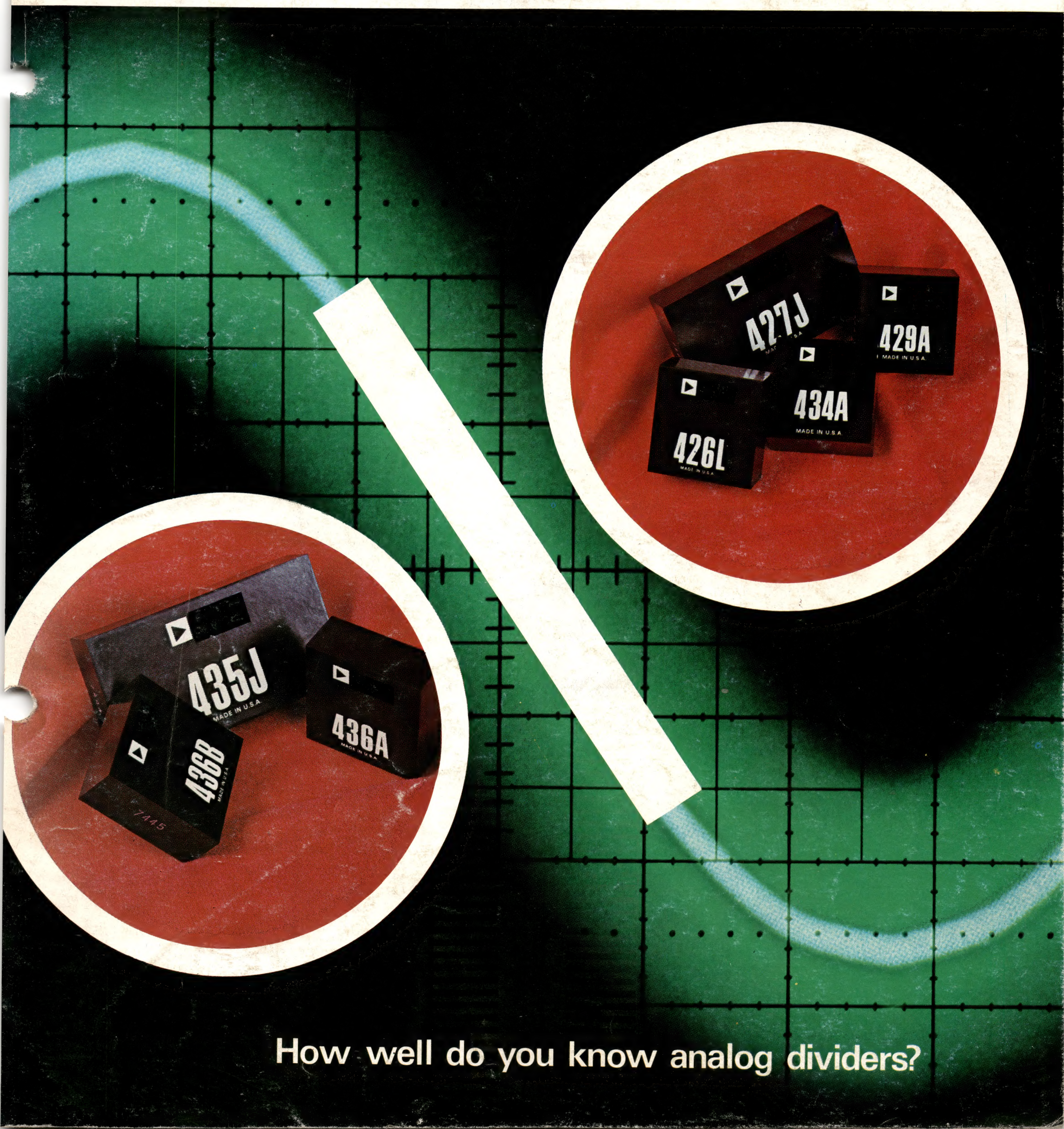
EDN

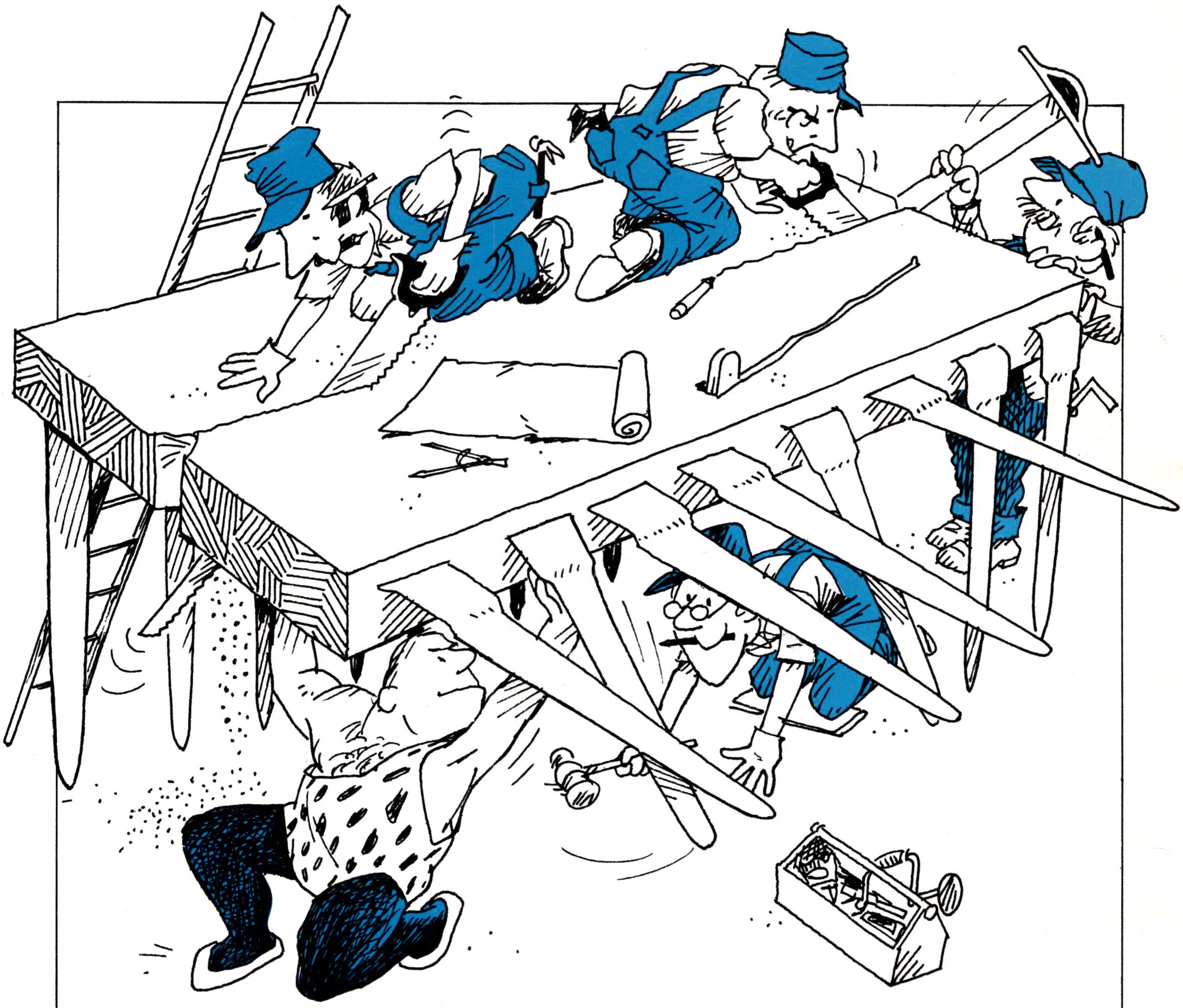
EXCLUSIVELY FOR DESIGNERS AND DESIGN MANAGERS IN ELECTRONICS

Designing precision differential rectifiers

Pitfalls to avoid in applying μP's



How well do you know analog dividers?



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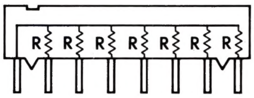
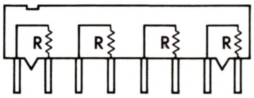


MODEL 784-3



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VOLUME 20, NUMBER 2

EDN

EXCLUSIVELY FOR DESIGNERS AND
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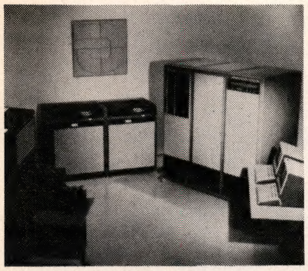
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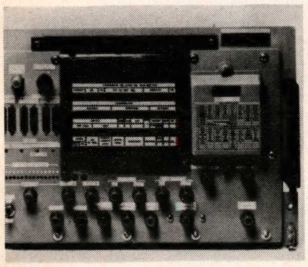
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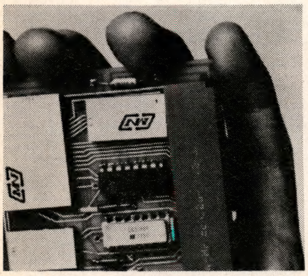
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COVER

Our popular series of "take home" exams continues with this issue's little quiz on analog dividers. Since the subject was well covered in EDN last year, there's no excuse for anything but top grades! Analog Devices supplied the cover photos and the exam, which begins on pg. 31.

BPA ABP

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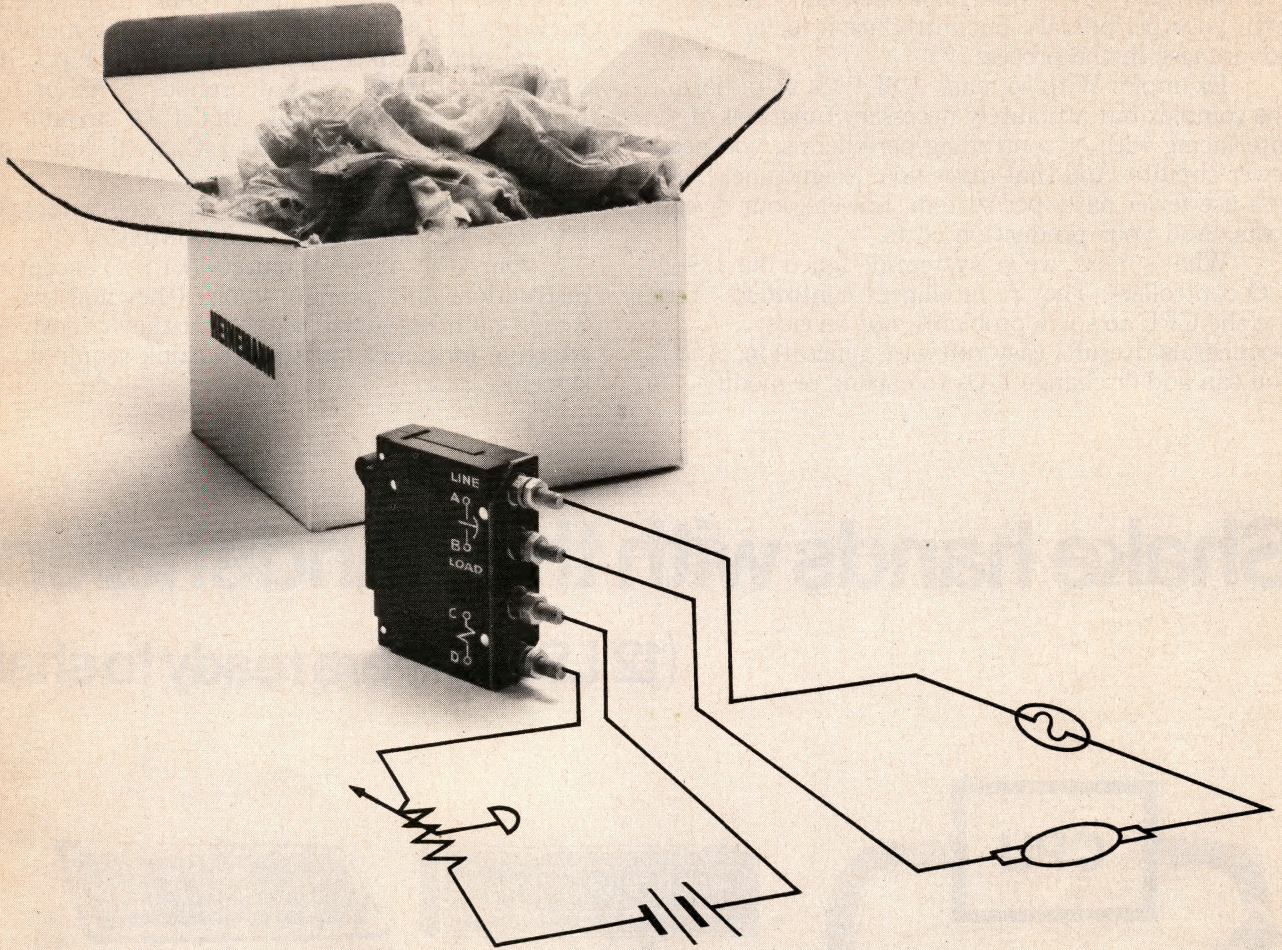


SURPRISE PACKAGE

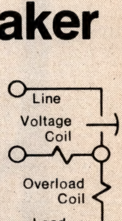
You can do a lot more if you have the right circuit breaker

It still surprises many engineers to learn that Heinemann circuit breakers can do things besides interrupt short circuits and overloads.

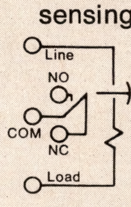
This one, for example. Note the four terminals. Already you know it's rather special. It disconnects the circuit of your choice under conditions other than overcurrent. Since it responds to a control signal (usually voltage) in a separate circuit, we call it a relay-trip breaker.

Relay-trip (one of seven special-function circuits available in most of our breakers) is very handy in preventing damage to equipment if *something else* strays off limits. Say you want to shut down a pump if fluid level in a tank gets too low or too high. Or stop a machine tool if the weight on the feed table suddenly changes. Just hook a Heinemann relay-trip breaker to the proper sensor, and save a lot of extra design work.

Another of our special circuits, Du-Con™ (dual control), gives you two coils, for both overcurrent protection and control-signal sensing, in a single-pole breaker.



In yet another, we throw in an integral 10-amp SPDT or DPDT auxiliary switch whose contacts transfer when the breaker trips, letting you energize alarm lights or emergency apparatus should the protected circuit be shut down.



We'd like to show you more. There's a lot more in our Ideafile #3 entitled *Control "tricks" that use circuit breakers.* Ask us for a copy. Heinemann Electric Company, Brunswick Pike, Trenton, N.J. 08602.

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We keep you out of trouble.

For more information, Circle No. 12

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5955

Rockwell Parallel Processing Systems (PPS) are more than CPU-ROM-RAM microprocessors. They're full-fledged microcomputers—with 12 LSI I/O controller options that not only shake hands with your peripherals, but introduce a lot of advantages in the process.

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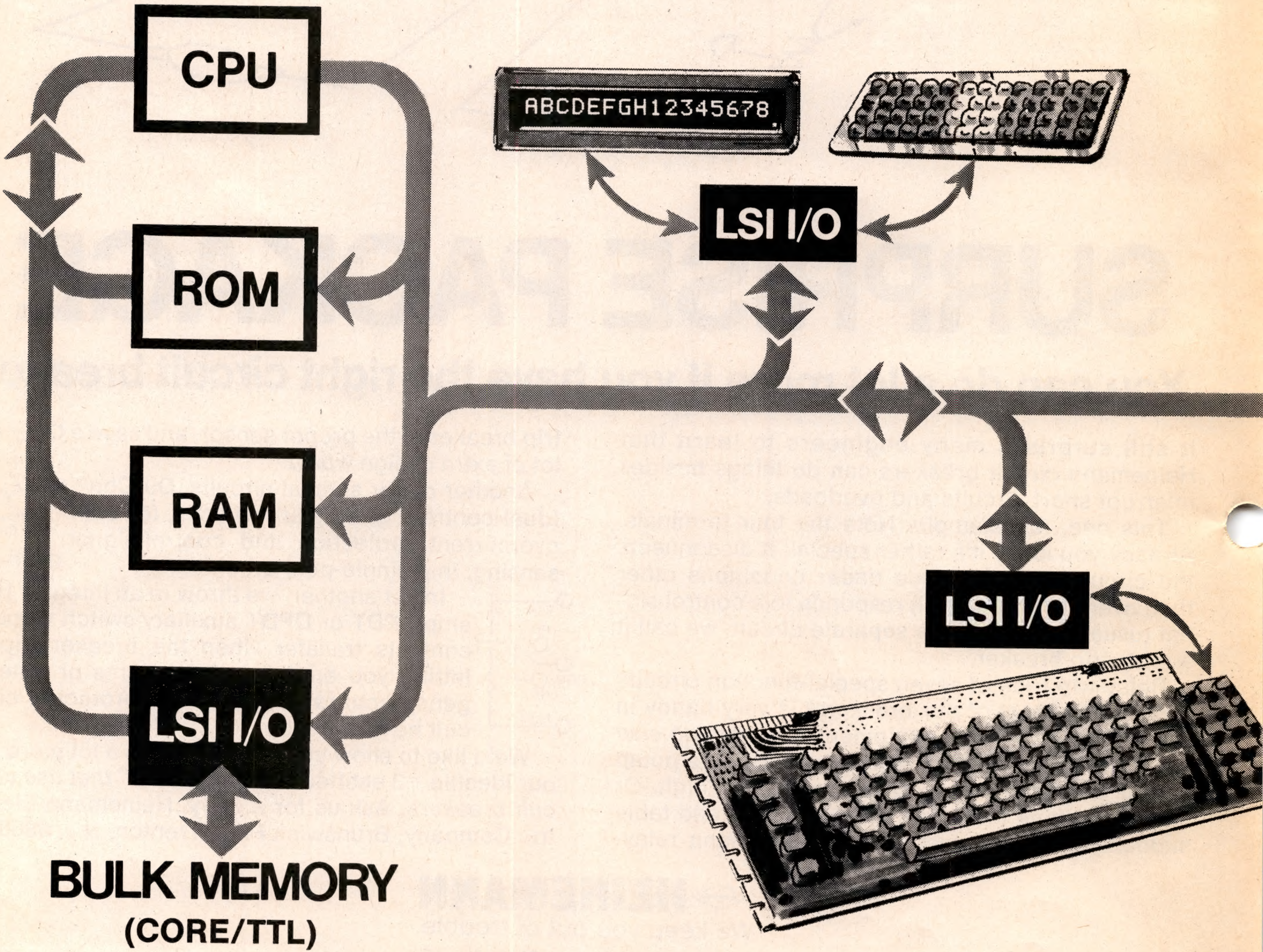
Shake hands with the handshaking

(12 LSI I/Os are ready to shake



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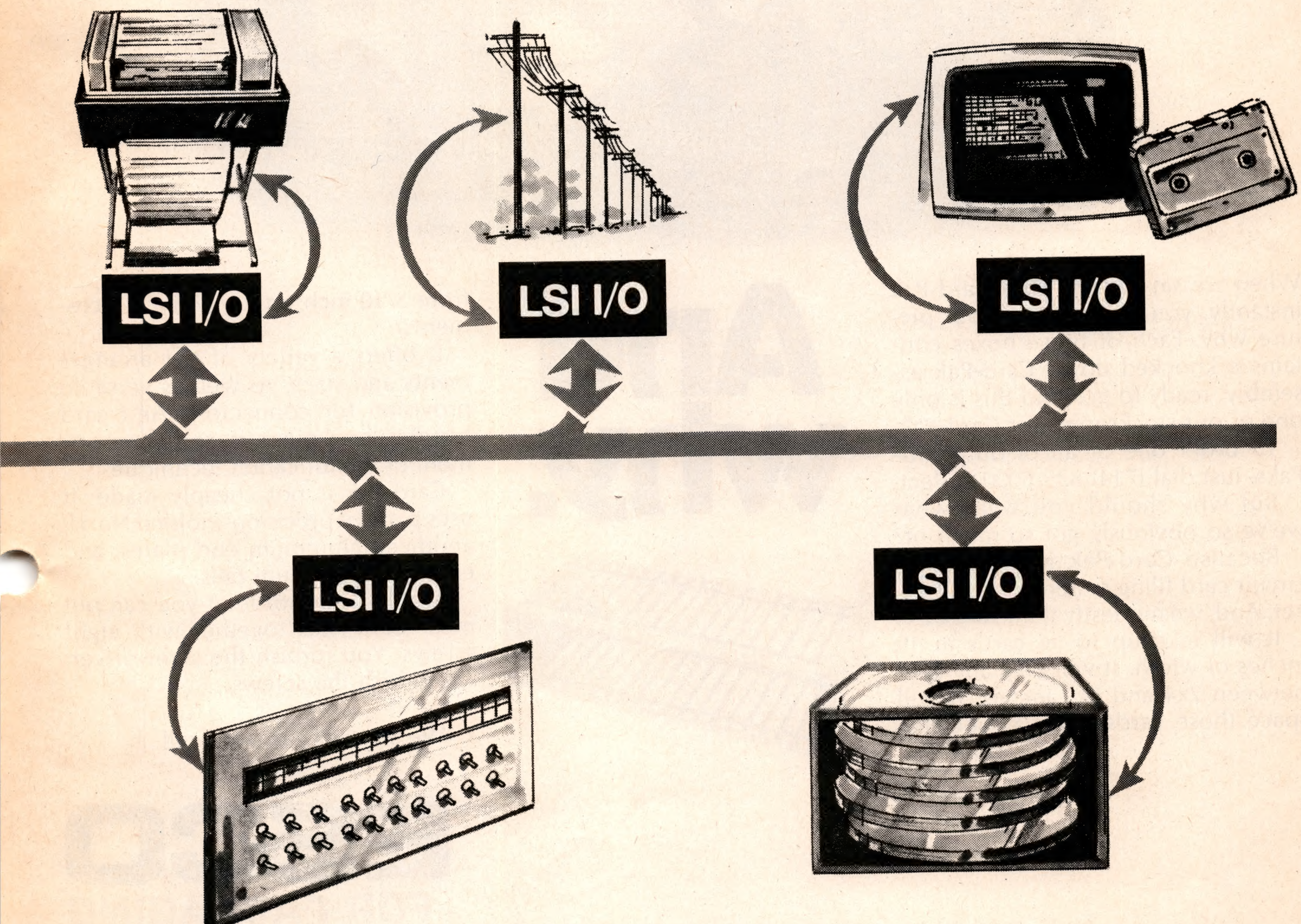

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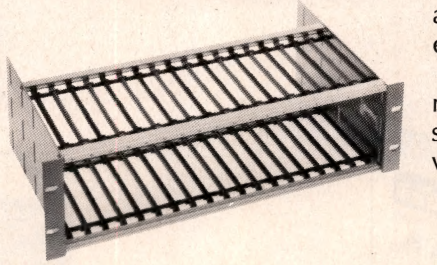

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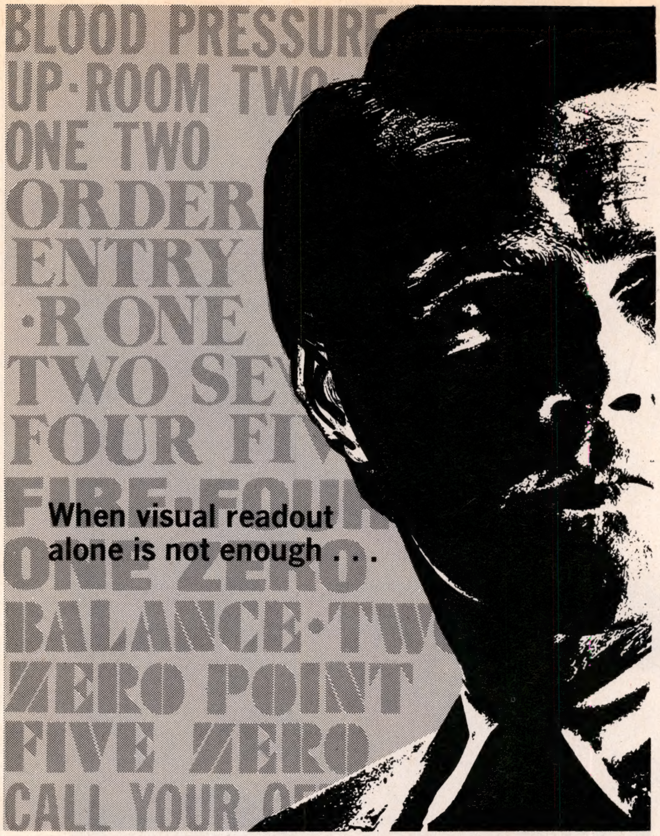

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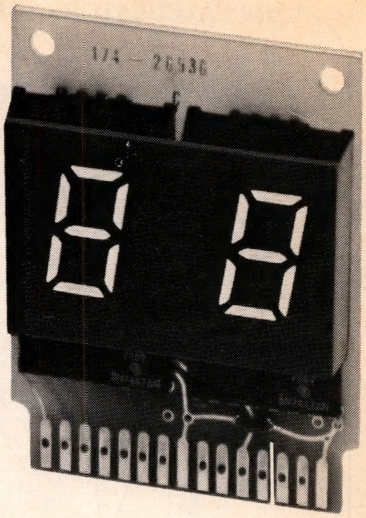

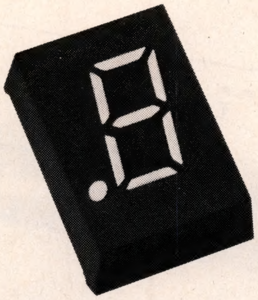

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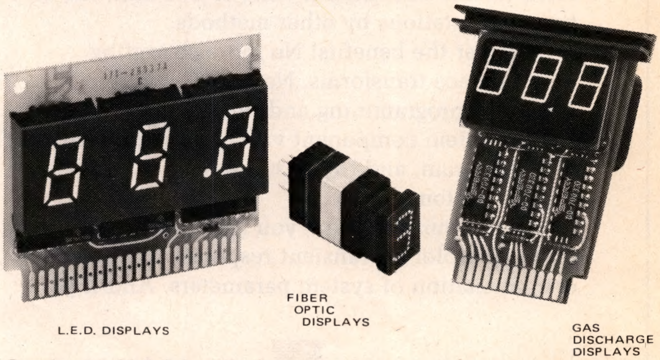

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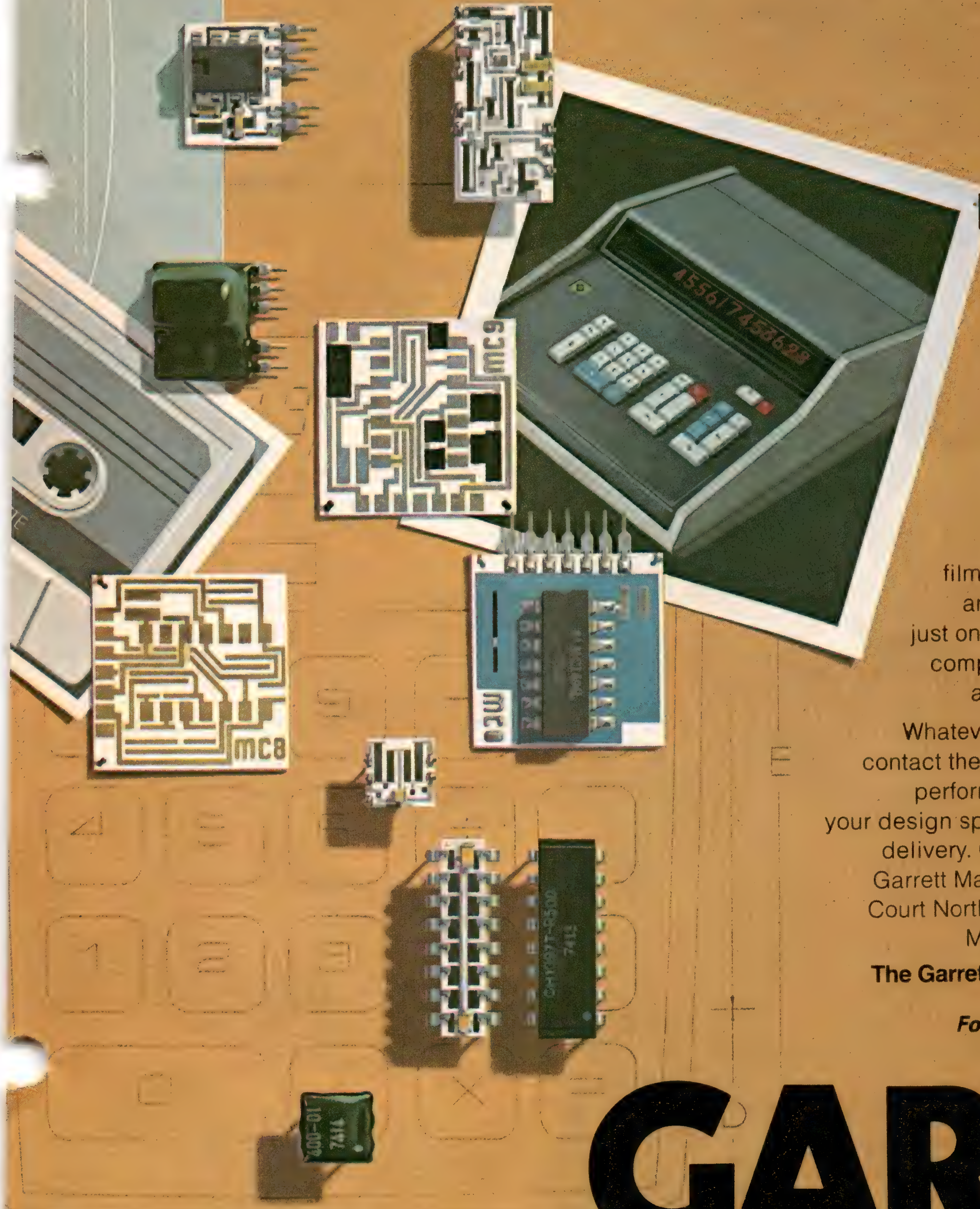

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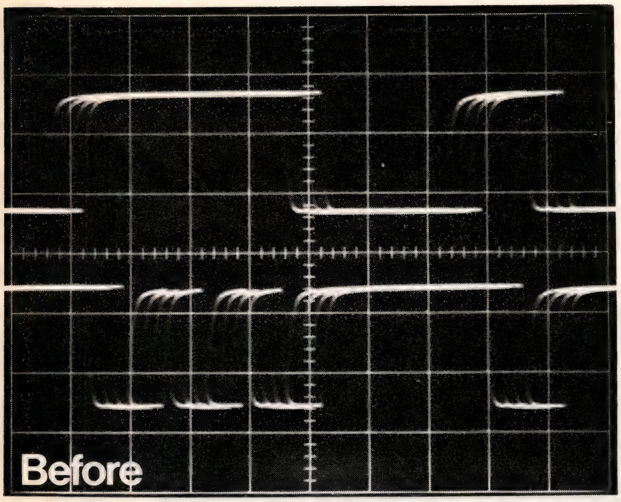
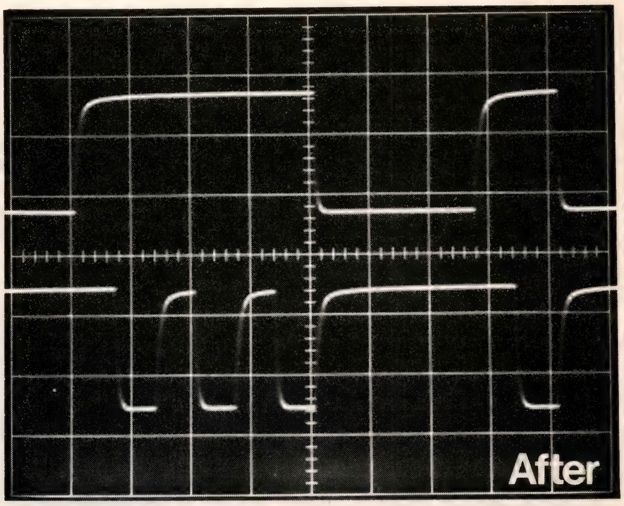
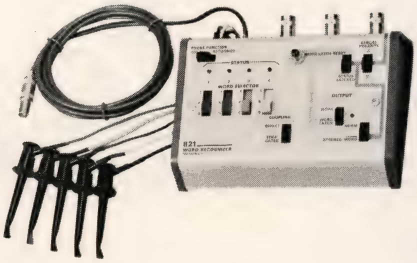
STABLE DIGITAL DISPLAYS-





TWO EASY WAYS



Logic Triggered Displays

Stable oscilloscope displays of asynchronous logic sequences are easily achieved with a trigger from the 821 Word Recognizer. And the 821 will work equally well with synchronous sequences that have no single unique sync point. As a trigger generator the 821 combines your choice of input logic signals to produce a single output pulse. Appearance of a specific op code in an instruction register, a predetermined count from a digital counter, or the occurrence of a special set of logic levels at your system inputs can all be used for jitter-free oscilloscope triggering.

And the versatile 821 serves as a logic "babysitter" to indicate whether a selected combination ever occurs, as an indicator of word presence or absence at strobe time, as a strobed four channel logic probe, and as a four channel logic level driver for troubleshooting static logic. All of these valuable logic diagnostic aids are offered in one pocket-sized unit for only $200.

For demonstration, Circle No. 4

Delay By Events Trigger

Select and display any data segment in a disc, drum, or tape memory. Examine serial data transfers. Study serial transmission. Jitter-free, delayed oscilloscope triggers for all of these applications, and many more involving long pulse trains, are easily obtained with the TEKTRONIX DD 501 Digital Delay. By basing the delay on a count of input digital events rather than an analog time, the DD 501 eliminates jitter due to mechanical speed variations or other clock irregularities.

Easy thumbwheel selection of any delay count from 0 to 99,999 provides quick positioning of the desired data segment on the oscilloscope screen. Versatility has been assured by making the DD 501 compatible with all logic families. The DD 501 plug-in can be housed in any TM 500 Series Power Module. It is priced at only $495 plus the Power Module ($125 for the TM 501 shown above).

For more information on stable digital triggering the easy way contact your local Tektronix Field Engineer or write: P.O. Box 500, Beaverton, Oregon 97077. In Europe write: Tektronix, Ltd., P.O. Box 36, St. Peter Port, Guernsey, C.I., U.K.

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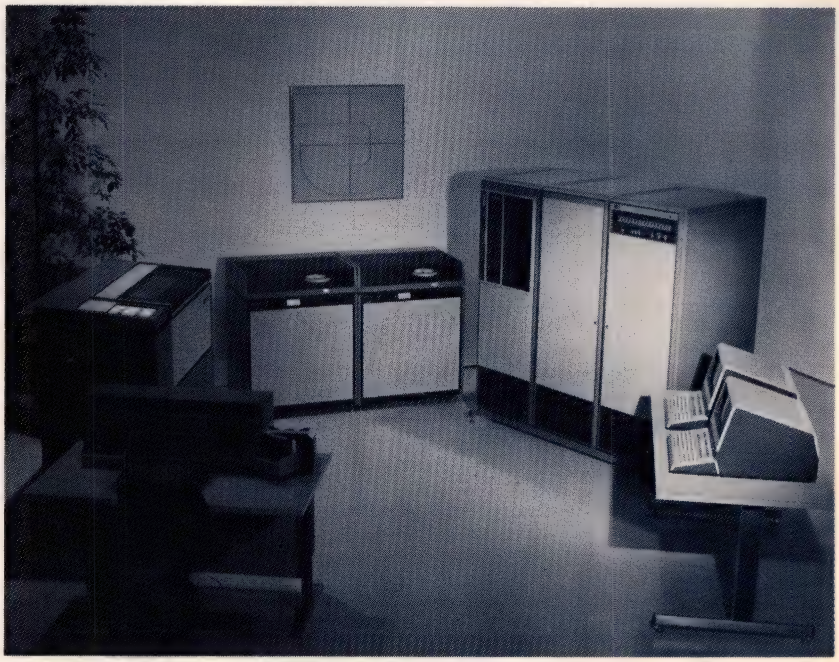
TEKTRONIX®

committed to
technical excellence

Unique minicomputer architecture reveals industry's coming of age

Designed to meet the needs of distributed computer network users as well as those with single-unit dedicated requirements, Hewlett-Packard's HP 3000 CX series features a unique architectural philosophy. A single multiprogrammed operating system, MPE/C, permits I/O spooling for more efficient use of peripherals and also provides full language capability for COBOL, RPG, BASIC FORTRAN and SPL, HP's systems programming language.

Purpose of this design was to make possible the implementation of multiprogramming, multi-lingual, virtual memory operation without requiring expensive hardware and large amounts of money.



Top of the line in Hewlett-Packard's 3000 CX minicomputer family is this system 300 CX.

Code separate from data

In most computer systems, programs consist of an intermixing of instructions and data. Within a subroutine, the compiler reserves program locations for return addresses to other subroutines. Space is set aside for the storage of local variables. Also, each program runs independently of the others so that no advantage can be gained if each is actually executing the same program. Because of this, it is very difficult to write reentrant (shareable) programs on conventional machines.

HP's approach separates programs into those elements that do not need to be altered and those that do. This results in a program consisting of a separate code and data area. The code is unalterable by the user program, so it can be shared among all the users who need it.

A 32-bit LSI bipolar ROM-based μP forms the basis for the 176 instruction code. Additionally, there is no instruction available in this set that allows the user to modify his program.

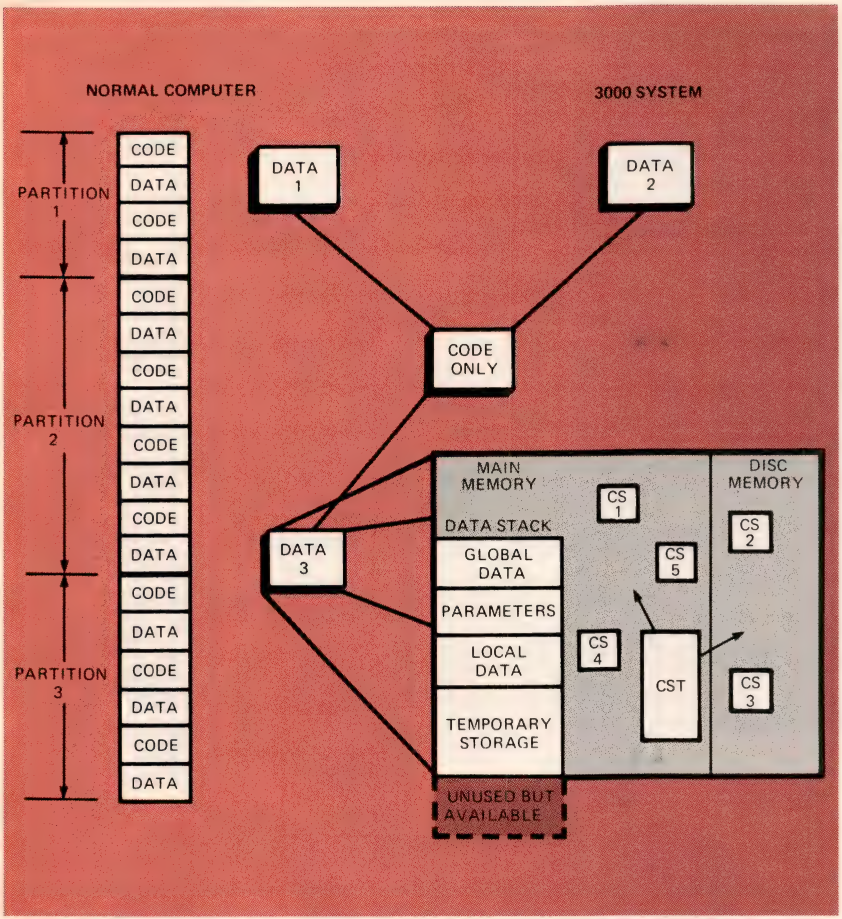
Each user also has his own unique data area. This contains all of his program's global variables, parameters used for subroutine calls and return addresses. If more than one user utilizes the same program, then the code of that program is shared by all. Nevertheless, each user still retains his own separate data space.

As a result, simultaneous execution of programs needs less total memory (both main and disc) than if multiple copies of the same program were required.

Also, the user does not need a special programming effort to have shareable code segments. However the code is produced, it is automatically shareable. Even the operating system can be shared.

Divides segments logically

Code segment lengths are



Main differences between normal computer and HP's new architecture are separation of code and data, variable code segment lengths and dynamically allocated data stack.

variable, as opposed to the paging method of most virtual memory systems. Segmentation is only allowed at the program module level; it cannot take place within a subroutine. However, one can take a single subroutine and place it in one of many code segments.

This eliminates the possibility of segmenting in the middle of a critical DO-loop—a very real possibility in systems that arbitrarily segment in, say, 4k segments. Execution would then entail thrashing between one code segment and the other. This is why many programs execute much slower on virtual memory systems.

Not a panacea

The message here is that virtual memory systems are not the panacea for all programmers' needs. A good virtual memory system must allow the user the flexibility of tailoring his own segmentation scheme so that he can group segments of code that are most important into common units.

Segmentation takes place through control statements to the compiler or commands to the operating system. Once divided into code segments, the operating system and hardware take over management, and determine whether a segment should reside in main or disc memory. The management of code segments and the code segment table is completely transparent to the user program.

Resident in main memory is the code segment table. This points to active code segments in core or their addresses on disc. If a required segment is in core, transfer is immediate. If on disc, the segment generates an interrupt and notifies the operating system. It is then up to the operating system to make space for that code segment in memory in order for it to be executed.

The code segment table also contains status information on the frequency use of the segments. The operating system uses this information efficiently to determine whether or not a code segment should be in main memory or swapped out on disc. A frequently used code segment will remain in main memory continually.

Data stack varies

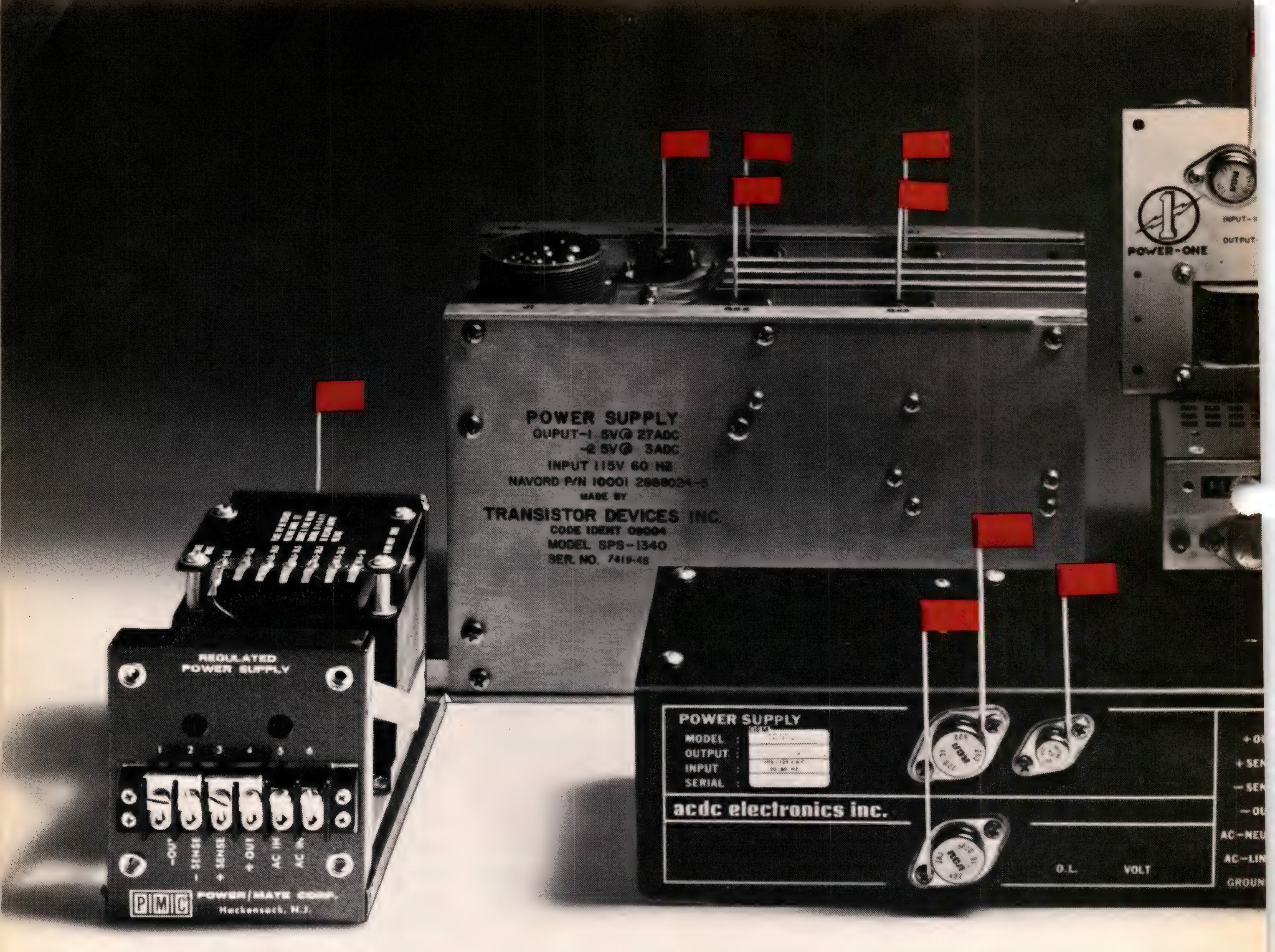
The data area of memory expands and contracts as the program requires. This data stack contains global data required by all subroutines during execution, parameters passed to subroutines, local data for currently active subroutines, and a temporary storage for evaluation of expressions and intermediate results.

Memory management performed by the operating system is always in terms of the smallest amount of data stack area necessary at any point in time. Stack space is not reserved for possible future use. What is predetermined is the limit to which the data stack may expand. If this limit is reached, the operating system determines if further expansion is justified, and then acts accordingly.

The global area represents the minimum size of the data stack. This stack will grow to meet the needs of subroutines as they allocate storage for their working areas. When the subroutines have finished their job, the area is cut back. The next subroutine can then use the same memory space.

No space wasted

Programming tasks, such as dynamic allocation of storage,



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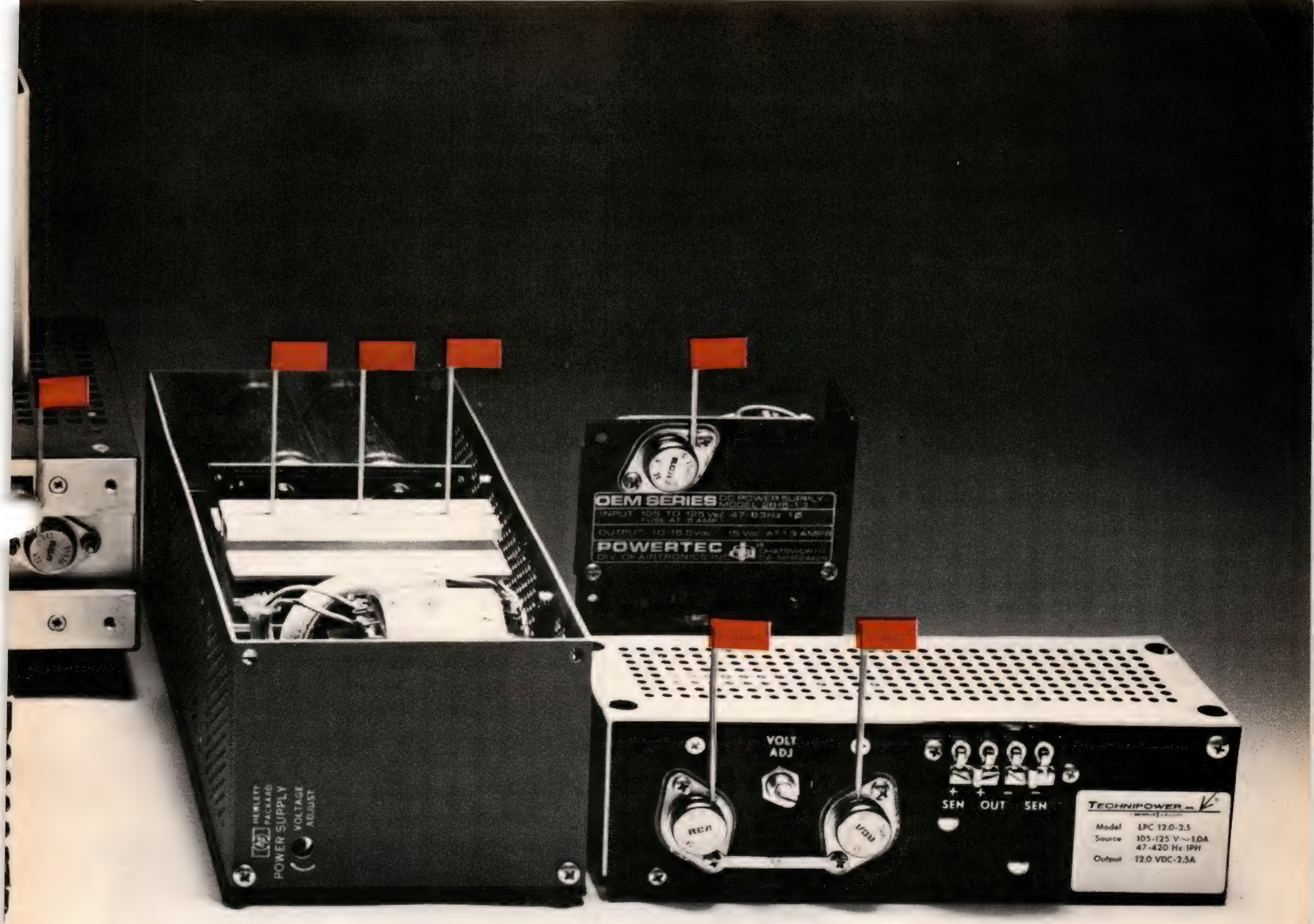

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are much more straightforward. In many programs it is not known until execution time how much storage is necessary for a matrix. A conventional system allocates enough storage for the maximum possible size. This, obviously, wastes a certain amount of storage because the space is not required in all cases. The dynamic system, on the other hand, allocates only what is needed during execution.

When a subroutine is called, the parameters required for passing information to and from that subroutine are loaded onto the stack. These parameters can be in the form of actual values or addresses to various variables within this stack. No other action is needed to pass parameters to subroutines. When the subroutine executes, it references the parameters directly out of the memory area rather than moving them into its own local area.

It is important to realize that this is a true hardware-implemented stack architecture, not a software-implemented "afterthought." The management of all areas within the stack is accomplished by the CPU and registers that point to the stack boundaries. The top elements of the stack actually reside in high-speed registers rather than main memory in order to optimize instruction execution speed.

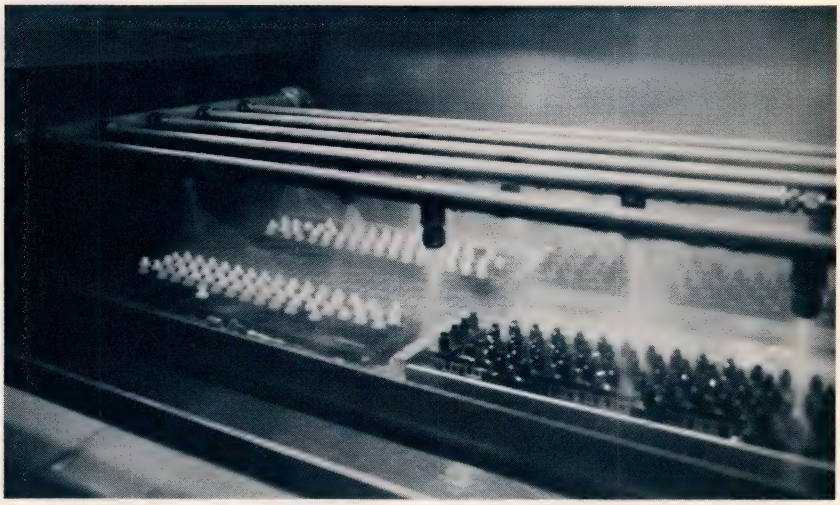
Better, shorter programs

To reiterate, in Hewlett-Packard's HP 3000 CX minicomputer family, tradeoffs between software and hardware allow each to perform efficiently the tasks for which they are best suited. Programs are small because the strong instruction set provides efficient code generation. The subroutine call process is very fast because of the large amount of work done by the microcode. These and other features dramatically improve the performance of the system without the normally expected increase in cost.—*RG*

Keyboard laundering washes away contaminants, leaves boards spotless

In normal use, all keyboards eventually become clogged by such culprits as spilled coffee or a buildup of lint or dust. Too often this calls for an expensive service call, but not for owners of the Hall-effect keyboards produced by Honeywell's MICRO SWITCH division. They're waterproof.

According to Honeywell, they need only be unplugged from their terminals, sloshed in detergent, rinsed and stacked to dry—just like dishes. In fact, they say, it is quite possible to perform the cleaning operation in a household dishwasher as long as the water can be kept below 135°F, which is the approximate temperature of most home dishwashers.



Detergent-and-water bath cleans excess flux from Hall-effect keyboards at Honeywell's MICRO SWITCH division. The approach also works well for unclogging boards in the field.

Taking 'em to the cleaners

Such a procedure fits field needs, too. Down-time for the most commonly applied washing technique need only be about 1 min./station. Typically, the preventive-maintenance crew enters an office, unplugs a given number of "dirty" keyboards, plugs in new boards and then hauls the "dunkers" off to a cleaning room. The next day the washed keyboards become the "new" boards and the cycle goes on.

At the factory, MICRO SWITCH puts all of its keyboards through a washing machine before shipment. A 6-min. high-pressure wash-and-rinse cycle removes excess flux from the pc boards. Until recently this had been a scrub-brush and chemical-solution hand operation. By using the washing machine they've saved thousands of man-hours annually, and helped reduce keyboard costs.—*ED*

Can medicine play it safe with computer technology?

A computer in Washington, D.C. can analyze electrocardiograms of patients in France and return the findings within 30 seconds. This feat, which utilizes a communications satellite, dramatizes the medical profession's increasingly intimate involvement with technology. Imaginative doctors foresee this producing great benefits to patients. Equally imaginative lawyers, however, foresee a whole new area of liability cases.

To tackle the problems that will undoubtedly arise in future court suits, a group of physicians, lawyers and computer experts recently gathered in Boston for what was described as the first "National Conference on the Legal Aspects of Computer Use in Health Care Delivery."

Sponsored by the Boston-based American Society of Law and Medicine and Massachusetts Blue Shield, the conference dealt mainly with the legal rights and liabilities of the various participants in the usage of computers in medicine.

More time for patient care

Besides the doctor-patient-computer relationship, the conference also focused on the problem of confidentiality of patients' records in computer banks. The lawyers felt that it may prove easier to protect the privacy of computer-held records than the traditional paper records.

Boston attorney Roy N. Freed, organizer of the conference, stated that, "Before computers, if you had a white coat on, you could enter the hospital and get anyone's records. But computers eliminate this danger." He also cited the advantages of such a system: There would be a reduction of clerical error; it would be easier to keep track of patients; and filing time would be almost eliminated.

Since health-care delivery consists largely of information processing, computers can now take care of these functions, thus freeing doctors, nurses and lab technicians for more important medical duties. Computers can also perform this "paper-shuffling" more efficiently than people, insuring greater speed, reliability, accuracy and volume.

So, if at your next check-up, the doctor pulls out of his little black bag a microcomputer in addition to his stethoscope, don't be surprised!—*CL*

Raising complex questions

Among the difficult issues discussed at the conference were the following thought-provokers:

- Can a doctor escape liability to a patient injured by his using a computer system to administer anesthesia?
- Is it legally safe for a doctor to fail to use a computer diagnosis system for pretesting?
- Do hospital charity patients have a right of privacy that guarantees freedom from routine treatment by medical students when computer-operated teaching dummies are available?
- Can a patient harmed by a flaw in a computerized intensive care monitor sue the system manufacturer on the basis of strict liability?

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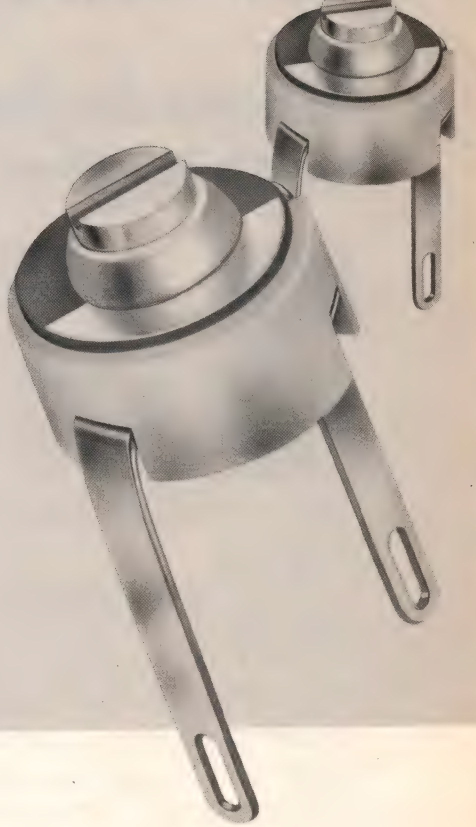

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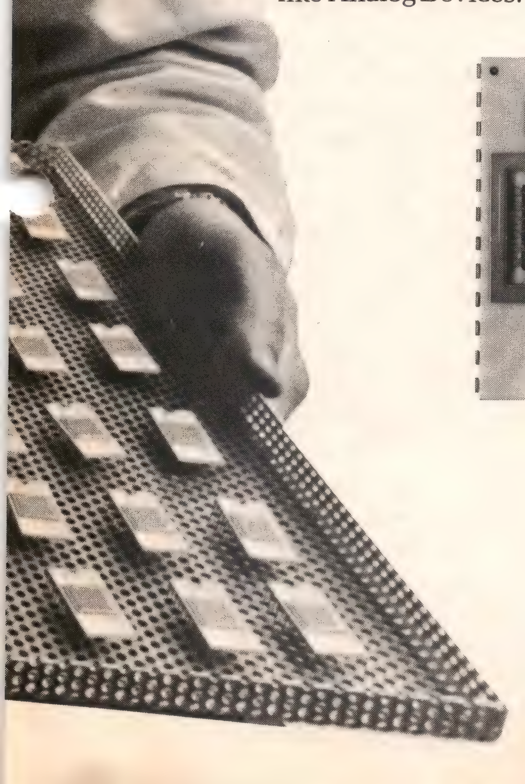

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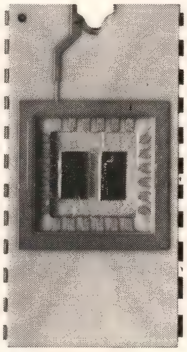

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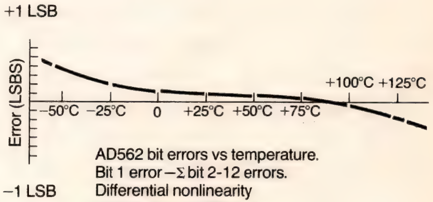

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Bit 1 error – Σ bit 2-12 errors.
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EDN µP DESIGN SERIES

Pitfalls to avoid in applying µP's

The early bird in an emerging technology is bound to make mistakes. Studying my µP experiences should help you escape the hidden traps.

Lee J. Mandell, Litton Data Systems

Two years ago, when I first started using microprocessors on military contracts, most designers were skeptical. The few µP's then available—mainly the Intel 4004 and 8008—were too new. They weren't second-sourced, and they weren't militarized. They certainly were not as well documented as a military component should be.

But I forged ahead—bit the bullet so to speak—and became one of those one-man µP software/hardware teams that seem to happen because of the µP's small physical size. Now, in retrospect, I can offer a few warnings on the subject.

But first I think it would help you evaluate my pointers if I told you how I was applying the µP's. My product was a communications unit for army forward observers (**Fig. 1**). It has a 64-character display and communicates with rear positions via radio lines at 1200 bps using FSK modulation. It can also communicate via wire links using digital signals. A microprocessor seemed a natural for this product because all communications had to be checked for reliability and security in an automatic fashion.

In my design, I used an Intel 8008-1 CPU either to do or to control directly all the unit's functions (**Refs. 1** and **2**). This included monitoring the front panel switches and keyboard functions, and performing the extensive self-tests, which allow isolation of faulty pc cards. I feel that the µP allowed me to make this product better than if I had used hard-wired logic. In addition, it allowed me to make proposals and implementations of follow-on versions for the customer more easily.

The pointers that I will give are based upon my experiences designing several models of this system.

Don't try to do it all in software

The majority of examples that have shown how µP's can replace hardwired logic have stressed the degree to which all logic can be replaced by sequences of programmed steps in the µP (software). In trying to hammer home the virtues of µP's, these examples have blatantly implied that the designer should now strive to eliminate every last external TTL package, doing the complete job with just the bare µP.

But hardware minimization is just **one** of your product design criteria. Other criteria still exist, such as system performance (now µP processing speed). Also, there is the new criteria of µP program-size minimization (which relates to ROM hardware minimization). If you forge ahead blindly, putting all hardware into µP software, you may violate one of these other criteria. Thus, you may lower your system performance or raise its total cost, and fail to achieve the product improvement you were hoping for.

An example along these lines from my own experience is shown in **Fig. 2**. I needed to serially output data into a shift register that was part of a LED display. (See **Fig. 3** for a picture of the display itself.)

Originally, I serialized the data by loading it into the 8008's accumulator and outputing it in the usual manner. This put the first bit on the A_0 or least significant output line leading to the serial shift register via a buffer flip-flop. Then, I rotated or shifted the accumulator one bit and re-outputted the data to get the second bit onto the A_0 line, and so on, until all the bits were out. The software steps listed in method 1 (given in their mnemonic abbreviations) indicate this sequence. The "OUT 1" put the desired data on the A_0 line (as well as, of course, putting the rest of the data from the accumulator on all the other lines of the 8-bit port), and the accompanying strobe (part of the 8008 system) produced the strobe-1 to gate it into the FF. Then the "RAR" shifted the accumulator in preparation for outputting the next bit.

This procedure just described would serially load into the FF as many bits of the data word as desired. To complete the transfer, I needed a way of pulsing the data from the FF to the display shift register. At the very start I had used an even more

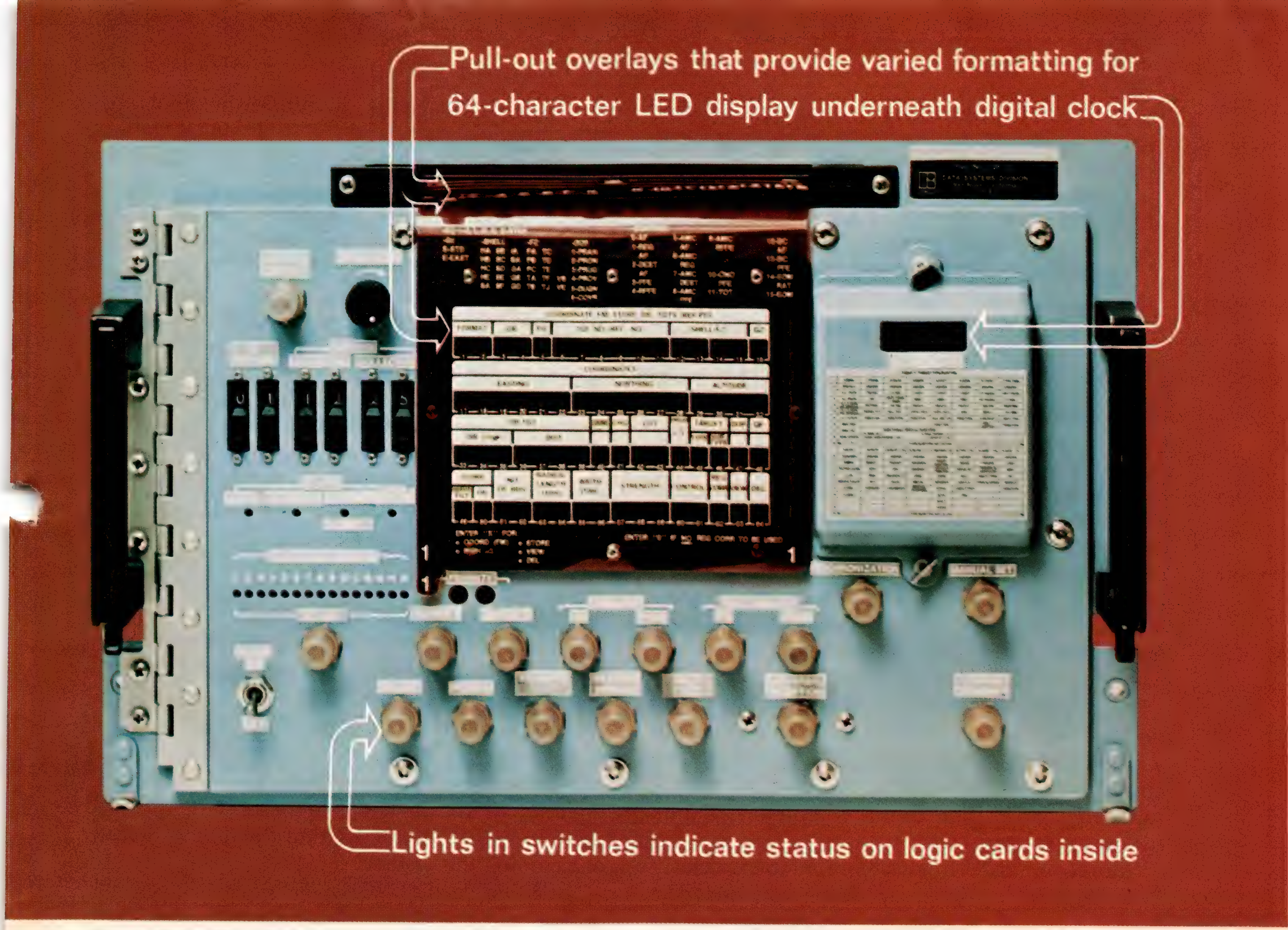

Pull-out overlays that provide varied formatting for 64-character LED display underneath digital clock
Lights in switches indicate status on logic cards inside

Fig. 1—This military field observer's communication unit gave the author his initial μP application experience. Many lessons were learned while designing the I/O and interfacing between the front panel displays and controls and the Intel 8008 μP inside. A military product, it needed constant self-reliability, self-checks and fault isolation.

inefficient means of producing these final strobe pulses than that shown in method 1. Alternating "LOAD IMMEDIATE ONE" and "LOAD IMMEDIATE ZERO" instructions jammed first a ONE and then a ZERO into the accumulator from program ROM. Then these were outputted to the port to produce the clocking pulses. This tied up the whole 8-bit system in just producing a pulse (the ONE) and then removing it (the ZERO).

Subsequently, I went to method-1's arrangement to produce the clock or strobe-2 pulses. The "OUT 2" instruction activated a second output port solely for the purpose of using its strobe. In other words, another port was addressed with an output command, and the accumulator data coincidentally sent out to that port. But the real purpose of the instruction was to produce a separate strobe that would cause the display shift register to load itself from the FF. This change allowed the single "OUT 2" instruction to replace four previous instructions—the two "LOAD IMMEDIATE's" and their respective two "OUT's."

The method-1 approach did indeed do the job mostly in μP software, as I thought I ought to be doing it. However, with the slow 8008, it took 750 msec to get the 64-character display out, tying up the whole computer for too long.

How could I speed up the data transfer to the display? My solution, method 2 in **Fig. 2**, was to ignore the "do it all in software" dictum and add the 8-bit PISO (parallel in, serial out) shift register. This enabled me to cut the software program down to the short, much faster, sequence shown. "OUT 1" puts all the bits of the 8008 word out into the PISO in one fell swoop. Then, the three "OUT 2's" shift the desired three bits serially from the PISO into the display.

Thus, at the expense of one additional MSI package, I reduced the software 10% and—most important—decreased the processing time by a factor of three.

How you get side-tracked

It may help you avoid such traps if I relate how I arrived at my initial design for the **Fig. 2** display loading function. I had started the project using the smaller 4-bit Intel 4004 μP. With the 4004, the original scheme of method 1 was an optimum way of doing the task for two reasons:

- The basic 4004 system has "free" output ports.
- The basic 4004 system does not have externally available strobes associated with its output ports.

The basic 4004, which was about all that was available in the way of a μP when I started my project, came out as an all-custom set of LSI chips (**Refs. 3** and **4**). The I/O ports were integral with the memory chips, so they tended to be "free" if you had even a modest-sized ROM and RAM requirement. Because the ports were integral with the custom memory chips, any strobes they might possess were buried inaccessibly inside. I therefore choose method-1's arrangement, retaining it when I switched to the 8008. Until I analyzed the efficiencies of various portions of my system, I did not realize the penalty I was paying for this carryover.

The real lesson to be learned here is that the μP designer must understand that he is dealing with a moving target. Therefore, each time he thinks about switching to a new μP—even one by the same maker—he had better completely rethink his entire design.

Moreover ... beware of simple-minded "rules," like "do it all in software," when you use μP's. Microprocessors are just too varied and complex to be attacked in a rote manner.

Don't hesitate to add intelligence

A corollary of the "don't try to do it all in software" caution is the admonition: "Don't be afraid to resort to redundant discrete logic at your I/O interfaces." With so much general-purpose intelligence residing in the μP, you tend to think it wasteful to add crude, old-fashioned, discrete logic intelligence. Yet the μP's intelligence has one glaring limitation—it is all performed in one place, the CPU ALU, and that bottleneck quickly becomes overloaded.

The multiple I/O's of real-time systems can saturate the CPU's ability to handle the incoming and outgoing data and control signal rates. Machine-to-man displays are notorious gluttons in this respect. The 8-character alphanumeric display of **Fig. 3** introduced me to this problem, because it was the unit loaded by the PISO serializer in **Fig. 2**.

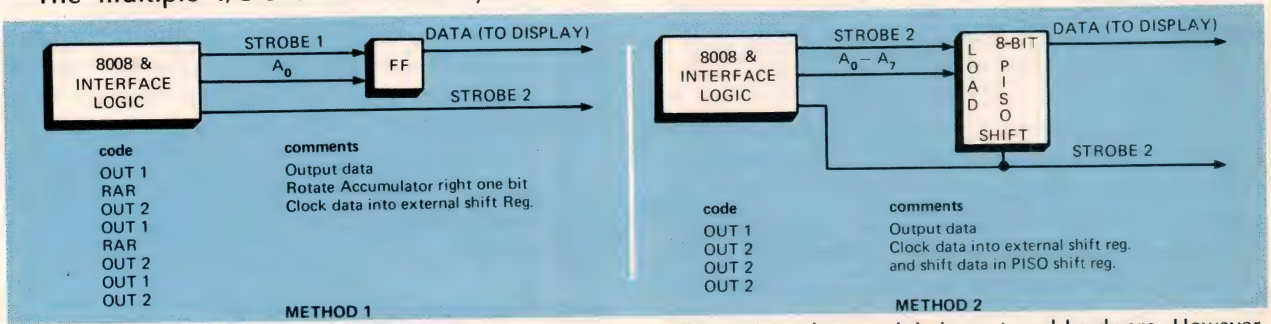
I needed to translate the system's ASCII data characters into the drive commands for the eight 5×7 LED display matrices. The μP could have done the entire job, feeding the dot patterns for the LED directly from its output ports. That, in fact, would be the way you'd normally think the job should be done, because then the μP uses its intelligence to replace the maximum amount of external logic. But to do so would have required a μP much faster than the 8008.

I came up with a compromise. I used the μP's intelligence to derive the dot pattern, but then had the μP pass this pattern to external logic for the actual driving of the display. The CMOS chips of this external hybrid multi-layer circuit (**Fig. 3**) stored the dot-pattern bit stream in a recirculating shift register. This shift register scans the readout across the eight display characters.

Thus I used the μP in a burst mode to generate the dot pattern, but had external circuitry free the μP from being monopolized by the repetitive task of scanning the display.

For I/O data inputs I typically use an external buffer to capture the data on its own, and then flag the μP. This flag from the buffer can activate the μP interrupt line (most of the newer μP's have interrupts). Alternately, it can be led to an I/O port, which the μP is programmed to look at periodically (software polling). The presence of the flag bit will cause the μP to branch a subroutine that will enable the buffer and input the data at a rate convenient to the microprocessor. Without this buffer, the μP would have to scan the input lines continuously (like a pocket calculator monotonously scans its keyboard). This would wastefully tie up the whole μP.

Apparently, this need for unloading the μP I/O with external buffering and intelligence is being



code	comments
OUT 1	Output data
RAR	Rotate Accumulator right one bit
OUT 2	Clock data into external shift Reg.
OUT 1	
RAR	
OUT 2	
OUT 1	
OUT 2	

METHOD 1

code	comments
OUT 1	Output data
OUT 2	Clock data into external shift reg.
OUT 2	and shift data in PISO shift reg.
OUT 2	

METHOD 2

Fig. 2—Hardware vs. software trade-offs are explored in this example. The task is to output three bits from the μP accumulator into an external display's shift register. Method 1 appears most attune to the new philosophy of maximizing μP software in order to minimize external hardware. However, the author found method 2 best for his application because, although it uses more external hardware (the 8-bit PISO), it halves the processing time and program size.

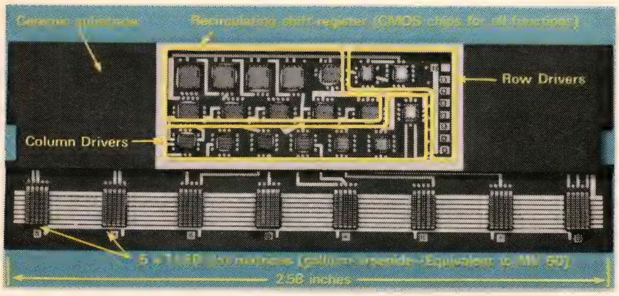

Ceramic substrate
Recirculating shift register (CMOS chips for all functions)
Row Drivers
Column Drivers
5 x 7 LED dot matrices (gallium arsenide–Equivalent to MAN 50)
2.58 inches

Fig. 3—An intelligent I/O unloaded the μP. Microprocessor derived the dot pattern, but this external logic actually drove the display. There is no sense in wasting the μP's intelligence by forcing it to do repetitive tasks.

recognized. Now suppliers are beginning to offer LSI support modules tailored to these requirements along with their basic CPU's. Rockwell and Motorola especially have been active in developing these support chips, and, in many applications, their systems will out "benchmark" other competing μP systems just because of the help the CPU receives.

Beware of software elegance

As the ex-hardware designer gets into software and begins to learn a bit of the programmer's black art, he finds himself constantly striving to prove that he, too, can construct tightly packed and elegant programs. He finds himself constantly on the lookout for parts of the program he can put into loops or subroutines that he can use over and over again. But while this elegance may save him lines of ROM, it may also slow down the execution of his program.

There is an unavoidable tradeoff between program size and processing speed. The CALL and JUMP instructions that are necessary for incorporating subroutines and the LOOP instructions (initialize decrement and test a loop-control register) all take time. The computer has to stop and do overhead steps.

I have learned that the tendency to be elegant and use lots of CALL's and JUMP's and LOOP's should be avoided when the payoff is low. Even when the payoff in ROM line savings is high, a critical speed requirement may render them undesirable. So be prepared to have your programs look crude to the professional programmer when fighting time in a real-time application.

Fig. 4 illustrates a situation of this type. I needed to generate eight clock pulses to shift data out. My final program, program 1, did the job in the most direct and nonelegant manner imaginable. But though it took one extra line of code than the usual elegant LOOP approach (program 2), it was over three times faster.

Keep in mind that program size efficiency is being measured in increasingly larger "granules" as larger and larger ROM's become available and economically attractive. If your program is 2-1/2k bytes long and you are using three 1k ROM's, you are wasting your time if you try to cut it down in size. Unless, of course, you can get it under 2k bytes and, thereby, dispense with the third ROM. If your optimization efforts cause a system delivery schedule slip, your program's elegance won't be accepted as justification by your managers or customers. Microprocessors allow fast turnarounds on designs, but not if you throw the time away. It's probably best to get the design done on schedule and then ask management or the customer if they think it would be worthwhile to try to eliminate excess ROM's as a retrofit.

Implementing system self-checks

Self-checks are very desirable in military systems. With microprocessors, I've found that it is relatively simple to program in a variety of system self-checks. You can even go further, as I did, and program in subroutines to isolate the cause of faults that the self-check exposes.

For communication systems, self-tests amount to periodically establishing an internal loop between the transmit and receive paths, and then having the μP exercise that path with known signals, testing to see if the proper responses occur. Known initial states can be applied to input-only paths, and then the system response tested. Depending upon how ambitious you want these tests to be, you can program any tests from simple static signals to complex frequencies at various duty cycles. For output-only paths, you can have the μP generate "lamp test" sequences that will allow the operator to detect faults.

It is difficult to have the μP CPU check itself because that test, of course, must assume that the μP CPU itself is functional. There are, however, checks you can make of the other elements of the system, such as the ROM and RAM memories. You can do check sums of the ROM program memory, as well as read/write and crosstalk checks of all bytes of RAM.

During the RAM test, be careful not to rely on the RAM for any loop counters. For example, don't store in RAM the address loop counters that you use to cycle through the RAM locations. Some of the older μP's like the Intel 4004 and 8008 are better than the newer models in this respect. The newer 8080, for example, stores its subroutine stacks in RAM rather than in the CPU chip as did the 4004 and 8008. Obviously, you should not be using the device you are testing (the RAM in this case) as part of your test program. Unfortunately, you can't avoid using the ROM when you are testing ROM, for typically your program will be stored in the ROM.

Checklist Before Embarking on μP Design

Use these five questions as a cautionary final evaluation before launching into a μP application project. They'll prevent you from using a μP just to say your product has one when you could be doing a better job with familiar hardwired logic.

1. Can the μP (as shown in the preliminary design) be replaced with hardwired logic?
2. How will the relative costs of the two approaches really compare in production? (Will the life of the product be long enough to enjoy the future price breaks predicted for μP's?)
3. How often will the design need to vary in the future? (Will anyone really get around to doing upgradings?)
4. Does the application really call for the versatility of a μP? (You can achieve versatility with common diode plug boards.)
5. What are the maintainability requirements? (What, for example, is the training background of the customer's technicians?)

Remember that hardwired TTL, CMOS and ECL designs can be versatile if various options are made jumper-selectable on the pc board. They can also partake of computer architectural concepts (though on a modest scale) and use custom microprogrammed ROM's and PLA's to achieve the same software moldability boasted by μP's.

A compromise I have found to get out of this vicious circle is to add external hardware to supplement the self-tests. I use one-shots that are retriggered off I/O operations. Also, I set up my program to produce the pulses that retrigger these one-shots at a given rate, when everything is operating properly. For instance, I may use an input test from a keyboard or an output strobe generated at the successful completion of portions of the self-test. In this way I can keep tally on the success of the self-test externally, and don't have to resort to a counter implemented in RAM.

Where in the program should one put these self-checks? In the communication systems I've designed, idle times would often occur between messages. I filled these dead times with continuous self-checks that would just repeat themselves until a message came along. You might as well have the μP doing something useful like checking its readiness, rather than just waiting around.

I predict that as designers become more adept at working with μP's we will see many clever self-check schemes. You can gain a great deal for small investment. I've found that with just a 5% increase in hardware and a 10-20% increase in software, it's possible to provide self-checking that impresses customers. But while your main justification in adding self-checking will be to make your system more attractive to your customer, you will find these same features will help you as well. For example, they will speed up your progress during initial breadboarding and then during production-line checkout, because they will automatically locate design errors and bad chips. □

PROGRAM 1		PROGRAM 2	
CODE	COMMENTS	CODE	COMMENTS
OUT XX	Generate one clock pulse	LBI 8	Initialize Reg B = 8
OUT XX		LOOP OUT XX	Generate one clock pulse
OUT XX		DCB	Decrement Reg B and repeat loop
OUT XX		JFZ LOOP	until Reg B = 0
OUT XX			
OUT XX			
OUT XX			
OUT XX			

Fig. 4—Program 1 looks much less elegant than program 2, but it runs over three times faster. Both these programs generate the same eight clock pulses needed in the author's application to load a display.

Author's biography

Lee Mandell, a senior engineer with Litton Data Systems Div. for the past three years, received both his BSEE and MSEE from R.P.I. His article "Sine Wave Synthesizer Has Low Harmonic Distortion" was voted best of the year in 1972's Design Award contest. Presently working in the field of microprocessor applications, Lee enjoys tennis and skiing.

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(These articles are all contained in EDN's 112-pg. μP Design Series reprint, available for $6.95 ea. from μP reprints, EDN Magazine, 221 Columbus Ave., Boston, MA 02116. Check or money order payable to EDN μP Reprints must accompany order.)

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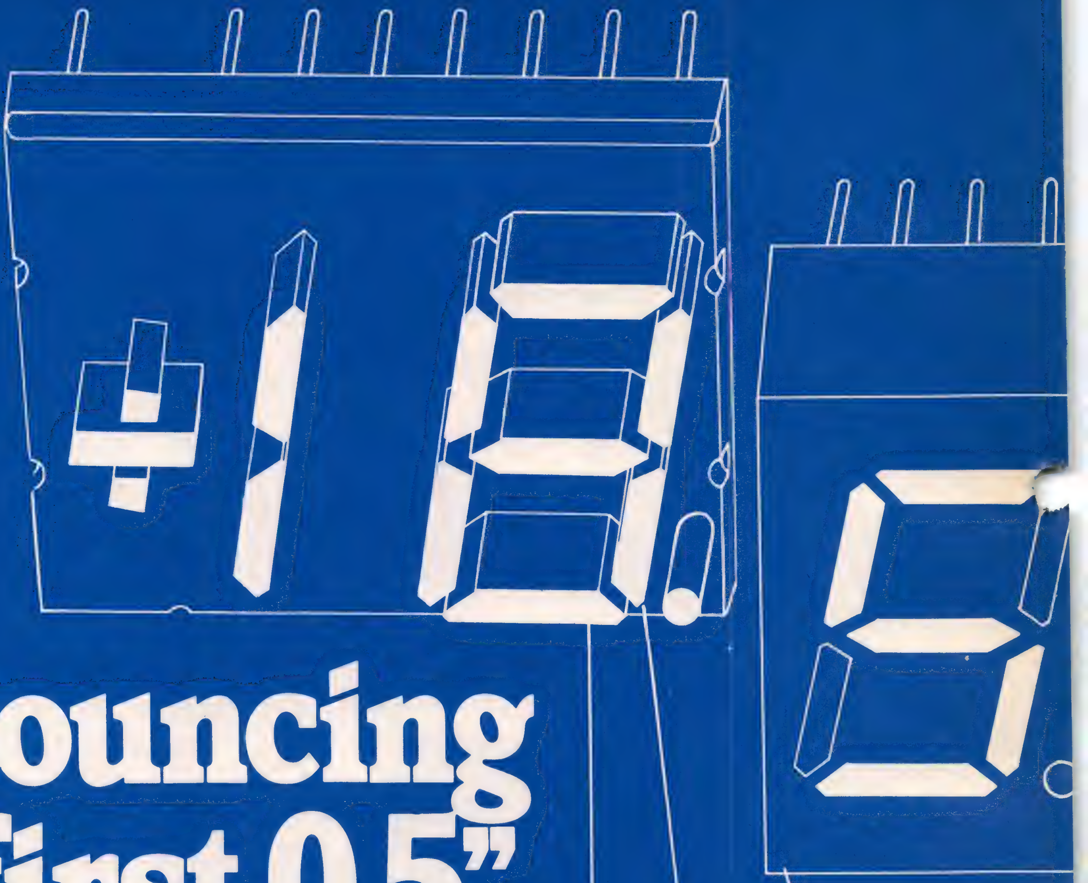

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two digits

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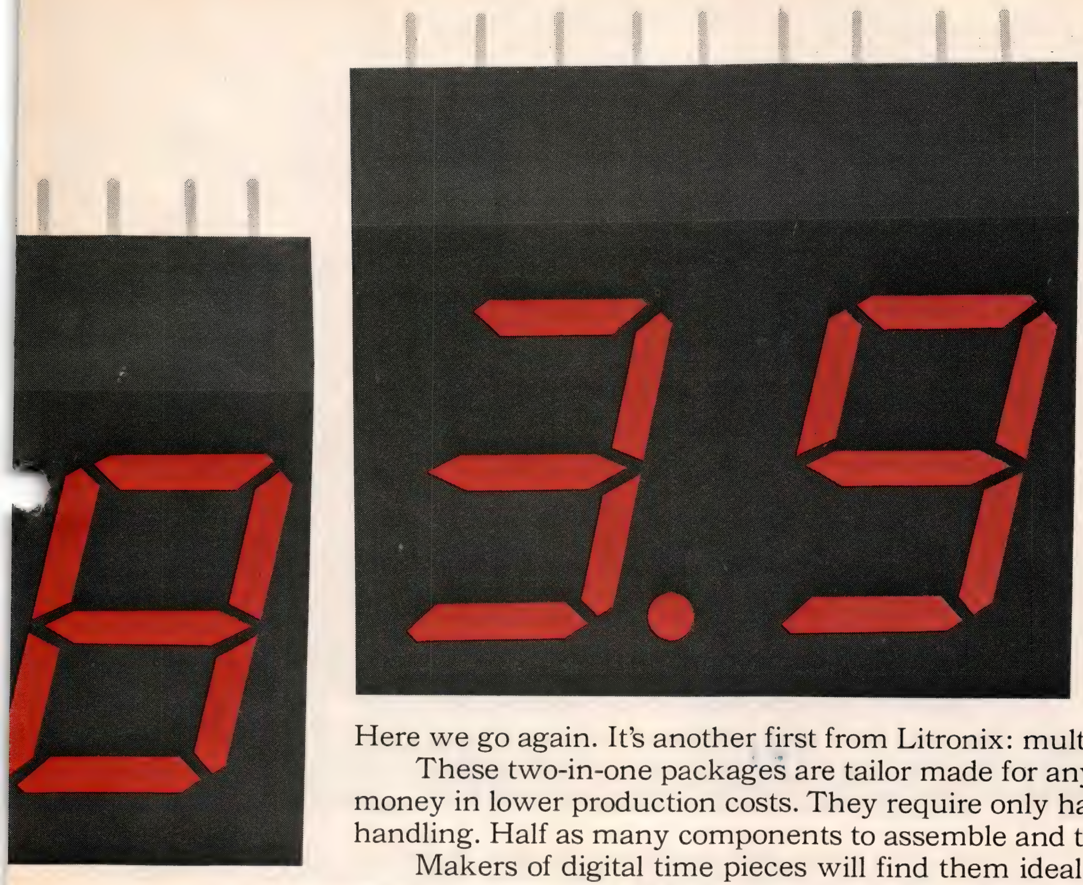
illumination evenly
over broad segments



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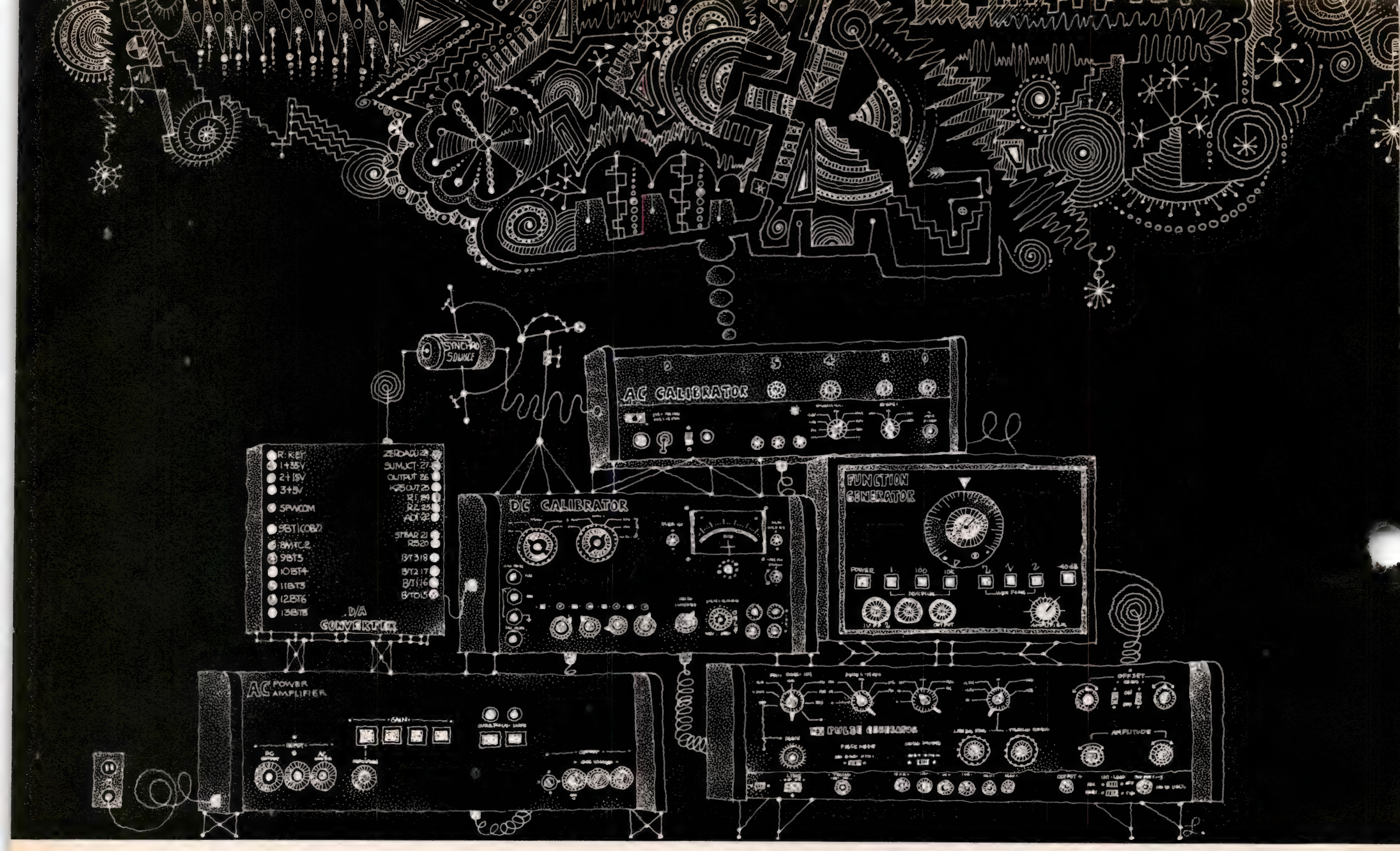

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V_o high range	—	65V	110V 110V
I_o	100 mA	1A	0.5A
Resolution	1mV 1mV 100μV* —	1mV 1mV 100μV* —	1mV 0.5mV 100μV* —
Programming	BCD binary	BCD binary	BCD binary
Settling time	30 μs	100 μs	110 μs
Programming noise (PK)	50mV —	50mV 100mV**	50mV 100mV**
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*optional			**high range

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Test your analog divider IQ

A little information can certainly go a long way. But do you know some of the things you should about analog dividers?

Lewis Counts and **Dan Sheingold**, Analog Devices

Analog dividers measure or establish a ratio, such as efficiency, attenuation or gain, impedance or other similar quantities. They are also used as gain-setting elements in such applications as AGC and adaptive control loops.

Problems arising in practice include choice of circuit configurations, determining scale factors, predicting bandwidths and errors from the specs, and selection of proper adjustment procedures. Simply dealing with a device that wants to have infinite output when one of its inputs is zero can be a source of problems.

Historically, the multiplier came first. Most present-day divider lore involves the use of multipliers in feedback loops. Indeed, most modern multipliers have the output-amplifier feedback terminals available forconvenient jumper-connection as dividers.

Low-cost multipliers have been considered as a promising possibility for division. Unfortunately, their low cost and convenience generally are not accompanied by the promise of high performance as dividers. The problems with multipliers used as dividers have led to the development and availability of committed special-purpose divider blocks: devices that exhibit better consistency of accuracy and bandwidth over wider dynamic ranges.

This quiz will trace the multiplier/divider's performance and problems, and provide insight into what's right, comparatively, with dedicated dividers. It will also test your knowledge of a few salient areas of application.

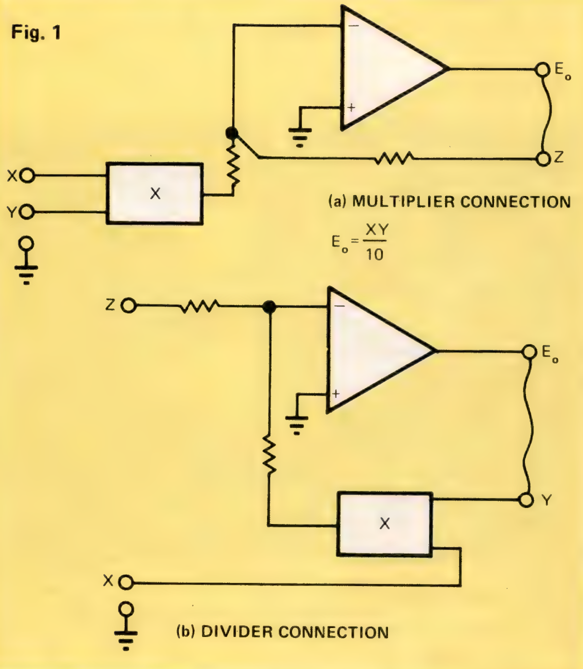
Ed. note: Device manufacturers have found that many of the customers' calls for help in applying a given class of products are repetitive versions of the same basic set of questions. EDN has published two quiz type articles[1,2], highlighting some of the commonly asked questions about op amps and PLL's. Reader response has indicated widespread acceptance of this format. We have, therefore, decided to apply the technique to inform our readers about other devices that are gaining widespread usage.

Out of 14 multiple-choice questions, pick the answer(s) you consider most nearly correct. The answers will be found elsewhere in this issue, along with a few comments on the principles involved.

Pencils ready? Begin!

One way of connecting most popular multiplier/-dividers is to use a feedback connection **(Fig. 1)**:

Fig. 1



1. If the circuit of **Fig. 1** has the multiplier transfer function indicated, and provides the true algebraic polarity in all four quadrants, what is the transfer function when the device is connected as a divider?

a. $E_o = -10Z/X$
b. $E_o = 10Z/X$
c. $E_o = 10X/Z$
d. $E_o = -X/10Z$

2. For what polarities of Z and X does **Fig. 1** work as a divider?

a. Z positive or negative, X positive or negative
b. Z positive or negative, X positive
c. Z positive or negative, X negative
d. None of the above

3. Assume the multiplier of **Fig. 1** has 300 kHz small-signal bandwidth ("small-signal" < 10% of full scale), with a first-order rolloff. Used as a divider, what will its output signal level be if Z is an ac signal of 0.2V p-p @ 30 kHz, and X is dc with a magnitude of 1V and the proper polarity?

a. 0.14V p-p
b. 1.4V p-p
c. 0.2V p-p
d. 2.0V p-p

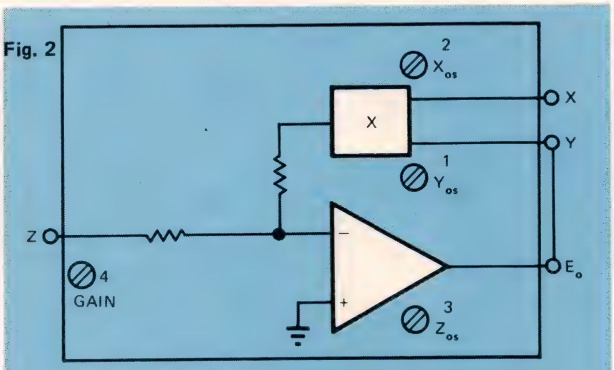
4. If the multiplier of **Fig. 1** has an untrimmed output offset of 10 mV, with the inputs at zero, what will be output offset as a divider when $Z = 0$, and the magnitude of $X = 1\text{V}$, with the proper polarity?

a. 1 mV
b. 10 mV
c. 100 mV
d. Output in limits

5. We could, if necessary, carefully trim this offset to zero. But, assuming multiplier offset tempco = 1 mV/°C, what overall drift might we expect as the temperature varied from 25 to 70°C?

a. 45 mV
b. 450 mV
c. 225 mV
d. Rapid drift into limits

Fig. 2



POT NO.	ADJUSTMENT	CONDITIONS Z MAGNITUDE	CONDITIONS X MAGNITUDE	ADJUST FOR OUTPUT MAGNITUDE
1	Y_{offset}	0V	10V	0V
2	X_{offset}	0.1V	0.1V	10V
3	Z_{offset}	0V	0.1V	0V
4	GAIN	10V	10V	10V

6. Fig. 2 shows a divider-connected multiplier with a set of adjustment pots and a table of adjustment conditions and effects. In what order should these adjustments be performed to retrim a multiplier for best performance as a divider?

a. 1, 3, 4, 2
b. 2, 1, 3, 4
c. 2, 4, 1, 3
d. None of the above

7. Given: a divider having the same transfer function as that of **Fig. 1**. For input ranges $0.1\text{V} \le Z \le 10\text{V}$ and $0.1\text{V} \le |X| \le 1\text{V}$, and X of the proper polarity, what is the magnitude of theoretical full scale?

a. 1000V
b. 100V
c. 10V
d. 0.1V

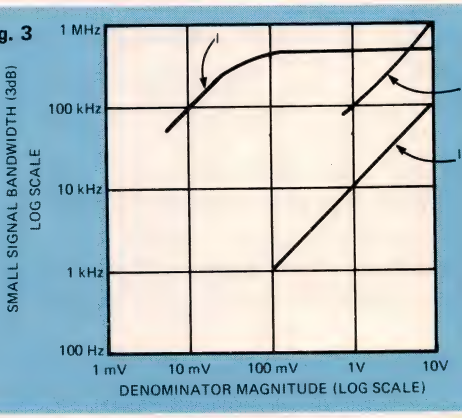
8. For conditions listed in problem 7, how should the inputs or output be scaled to get 10V F. S. output?

a. Nothing. It's already 10V F. S.
b. Place an attenuator following the output.
c. Amplify the output.
d. Attenuate Z and/or amplify X.

Figs. 3, 4 and **5** compare the performance of typical versions of the following types of divider:

a. Inverted multiplier (1% total-error class, as a multiplier)
b. Inverted multiplier (0.1% class, pulse-height-pulse-width)
c. Linearized 2-quadrant transconductance divider
d. Log-antilog divider

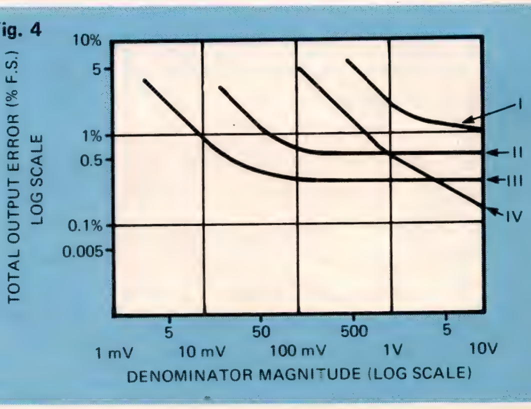
Fig. 3



9. Fig. 3 is a plot of denominator magnitude vs. small-signal bandwidth. For each curve, match the labelled performance to one of the four devices listed above.

Curve	Divider Type(s)
I	....
II	....
III, IV	....

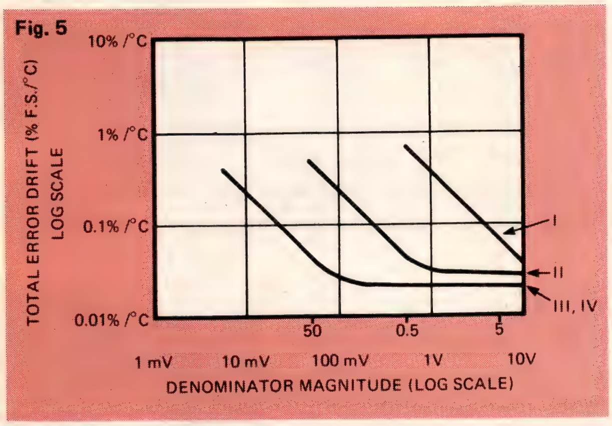
Fig. 4



10. Fig. 4 depicts total error vs. denominator magnitude at constant ratio (10V F.S. output), 1% F.S. is 100 mV. Match the curves to the divider types listed above.

Curve	Divider Type
I	....
II	....
III	....
IV	....

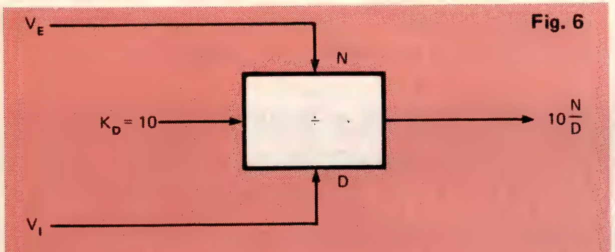
Fig. 5



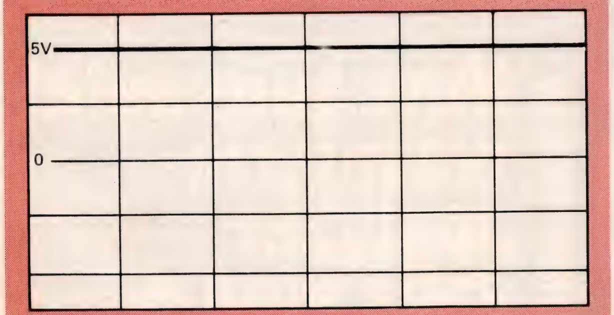
11. Total error drift vs. denominator voltage is plotted in **Fig. 5**. Match the curves to the divider types listed above.

Curve	Divider Type(s)
I	....
II	....
III, IV	....

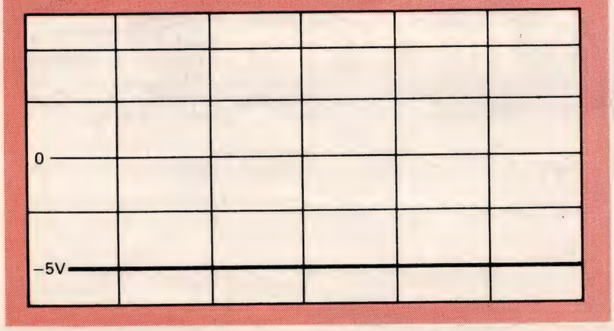
Fig. 6



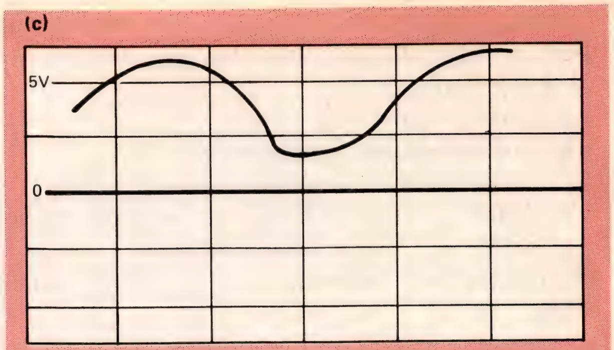
(a)



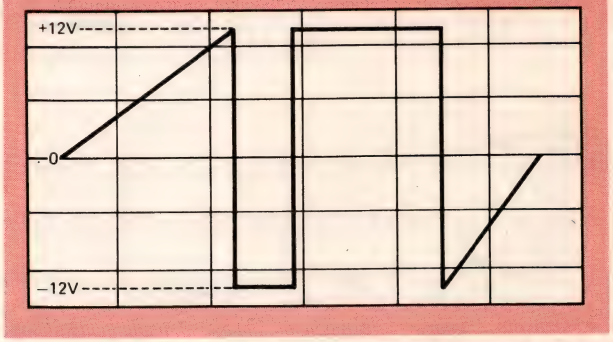
(b)



(c)

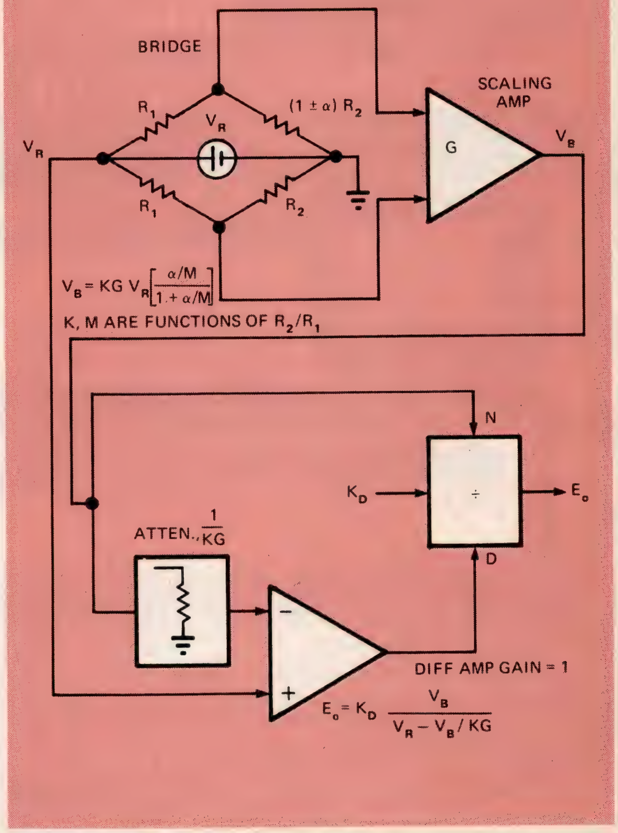


(d)



12. The circuit of **Fig. 6** is an obvious way to measure impedance, by the relationship $V_E/V_I = V_Z$. Pick out the waveform that most nearly shows the expected results of the measurement for $V_E = 5 \sin \omega t$ and $V_I = 10 \sin (\omega t + 45°)$, using the divider with a 10V scale factor ($V_Z = 5V \angle \underline{-45°}$).

Fig. 7


BRIDGE
R_1
V_R
$(1 \pm \alpha) R_2$
SCALING AMP
G
V_B
V_R
R_1
R_2
$V_B = KG\, V_R \left[\frac{\alpha/M}{1 + \alpha/M}\right]$
K, M ARE FUNCTIONS OF R_2/R_1
N
K_D
÷
E_o
D
ATTEN., $\frac{1}{KG}$
−
+
DIFF AMP GAIN = 1
$E_o = K_D \dfrac{V_B}{V_R - V_B/KG}$

13. Fig. 7 shows an instrumentation circuit that uses a divider. The purpose of the circuitry between V_B and E_0 is not to:

a. Linearize the bridge output
b. Compensate for V_R variations
c. Compensate for amplifier offsets
d. Allow a sensitive bridge to be used (higher values of K, lower values of G, M)

14. The equation defining the output of the circuit of **Fig. 7** is:

a. $K_DKV_R\frac{\alpha}{M}$
b. $KGV_R\frac{\alpha}{M}$
c. $K_DKG\frac{\alpha}{M}$
d. $K_DKG\frac{\alpha/M}{1+\alpha/M}$ □

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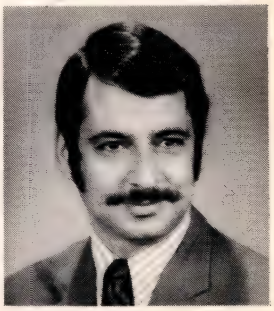
Authors' biographies

Lewis Counts is the manager for analog module engineering at Analog Devices' Modular Instrument Div. He received his SBEE from MIT, is an avid bicycle rider, and has long had an intense interest in nonlinear functioning modules. Lew has published numerous technical articles and contributed heaviiy to Analog Devices' "Nonlinear Circuits Handbook."



Dan Sheingold received his BSEE degree from Worcester Polytechnic Institute, and MSEE from Columbia Univ. He has had more than 20 years of experience in the design and application of analog computing equipment, conversion-products and function modules. Now manager of technical marketing and editor of "Analog Dialogue," Dan also edited Analog Devices' "Nonlinear Circuits Handbook."

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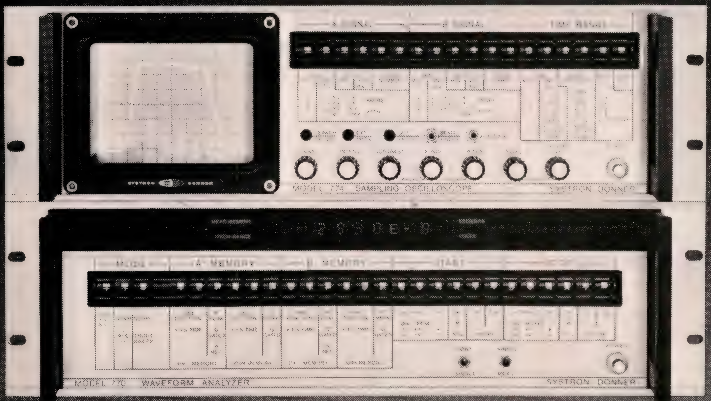

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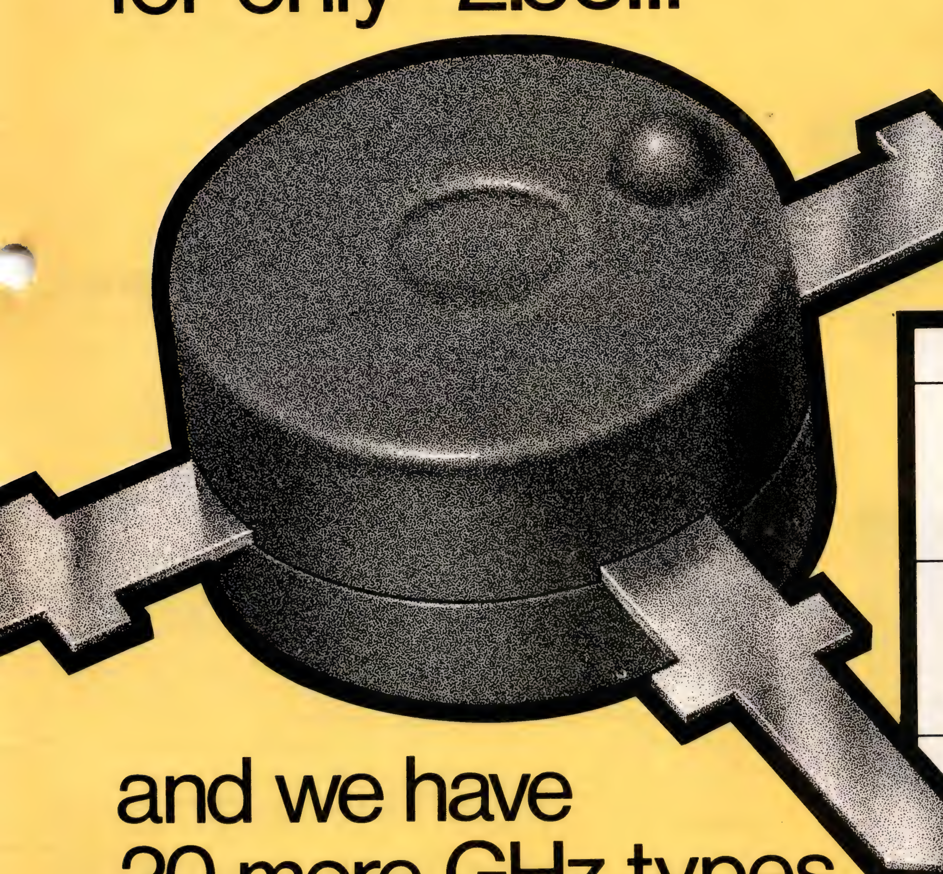

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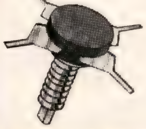
BFR94 	f_T (GHz)....3.5 @ 90 mA N.F. ....5 dB @ 500 MHz M.A.G. .....13.5 dB @ 500 MHz Package..Stripline Stud Price........$7.25 each*

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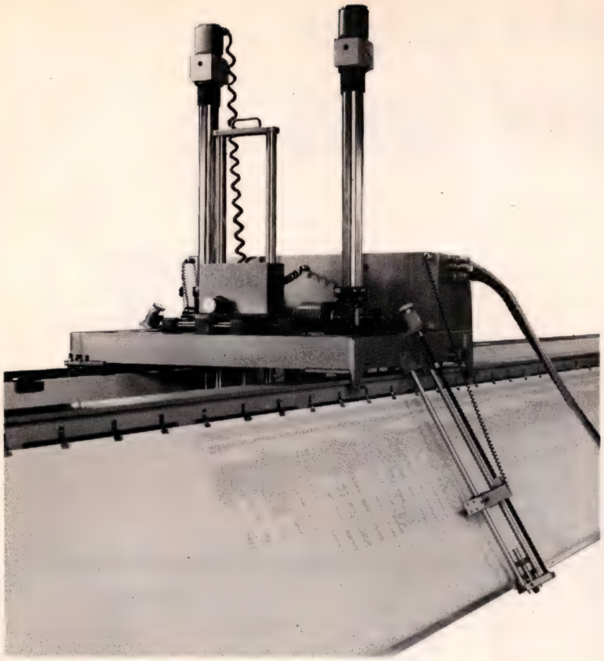

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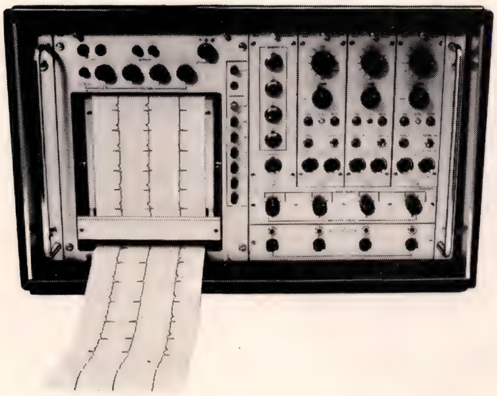

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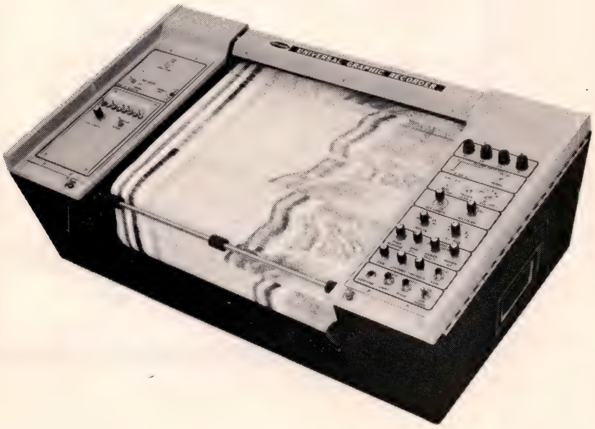

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Flexible discs: a look at the latest mini-peripheral

With no standardization in sight, floppy-disc users must be well versed in the basics to understand the differences.

Donald R. Reichel, Memorex Corp.

The concept of utilizing a flexible disc media has been present in the disc storage development arena for nearly a decade. Experimental work began within IBM around 1965, and it seems safe to assume that the flexible disc concept was experimented with in several other R & D laboratories during this same time frame.

It all began with IBM...

IBM developed a flexible disc product in response to internal requirements for a microprogram loader for several System 370 machines. A low-cost, random-access "permanent" memory was the essential requirement. "Permanent" meant both nonvolatile and noncustomer alterable. The result of these requirements was the IBM 23FD.

Since IBM was the only producer and user of flexible discs, independent peripheral suppliers that intended to compete had to follow IBM's lead. However, with OEM introduction, new applications quickly developed for the flexible disc drive.

As a result, we find in today's martketplace two principal efforts in flexible disc development—the "IBM compatible" and the "nonIBM compatible" drives. Product requirements exist for both drive types.

Why the diversity of specs?

Specifications and performance parameters vary widely according to whether or not the flexible disc drive is either IBM compatible or noncompatible. **Table 1** summarizes the range of specifications offered by both types.

The greatest number of the companies producing flexible disc drives use the configuration shown in **Fig. 1**. A lesser number of companies have in the past or are now producing flexible disc drives utilizing significantly different configurations. Rotating contact heads, noncontact heads, and fixed head-per-track configurations have all been implemented. Each of these offers advantages and disadvantages over the generalized configuration shown.

Maximum signal with minimum wear

Major components or subassemblies of the flexible disc drive include a base casting or frame; drive motor; disc guide; hub and clamp; read/write head; head positioning actuator; head load assembly; and a pc board that houses the electronics. The flexible disc media is, of course, the remaining major component.

When inserted, the disc is positioned by the registration hub that is centered on the face of the spindle. Closing the door moves a clamp that fixes the disc to this hub. The disc drive motor can then rotate the spindle through a belt-drive system. A stepped pulley usually is included to accommodate 50- or 60-Hz power.

TABLE 1
SUMMARY OF
PRODUCT CHARACTERISTICS

	NONCOMPATIBLE	COMPATIBLE
CAPACITY (FORMAT DEPENDENT)	3.1 M BITS (MAX.)	3.1 M BITS (MAX.)
ACCESS (TRACK TO TRACK)	10 mSEC	10 TO 40 mSEC
LATENCY TIME	80 mSEC (MIN.)	83.3 mSEC
NUMBER OF TRACKS	UP TO 77	77
NUMBER OF SECTORS	32	26
ROTATIONAL SPEED	UP TO 375 RPM	360 RPM
MTBF	> 2000 HRS.	> 2000 HRS.
MTTR	< 30 MIN.	< 30 MIN.

A stepping motor and integral lead screw form the head positioning actuator. All drives utilize a common 48 tracks/in., with only the usable length of the lead screw changing in order to cover either 64 or 77 tracks. The read/write head is mounted on a carriage that the lead screw moves.

Head load is achieved when the disc is lightly loaded against the rigidly mounted head by moving a load pad against the disc with a solenoid actuated bail (**Fig. 2**). Restraining the disc between the head and the load pad accomplishes head-to-disc compliance.

Achieving disc interchangeability

Two basic types of read/write heads exist. In the noncompatible case the head contains a read and a write element with the write element generally being three times as wide as the read element. Writing wide and reading narrow allows a normal deviation from the center of the track to have little affect on the signal-to-noise ratio. This permits disc interchangeability from unit to unit.

In the compatible case, the head contains a combination read/write element and then erase elements that "trim" the edges of the tracks. The trimming operation provides a tolerance band that allows disc interchangeability from unit to unit.

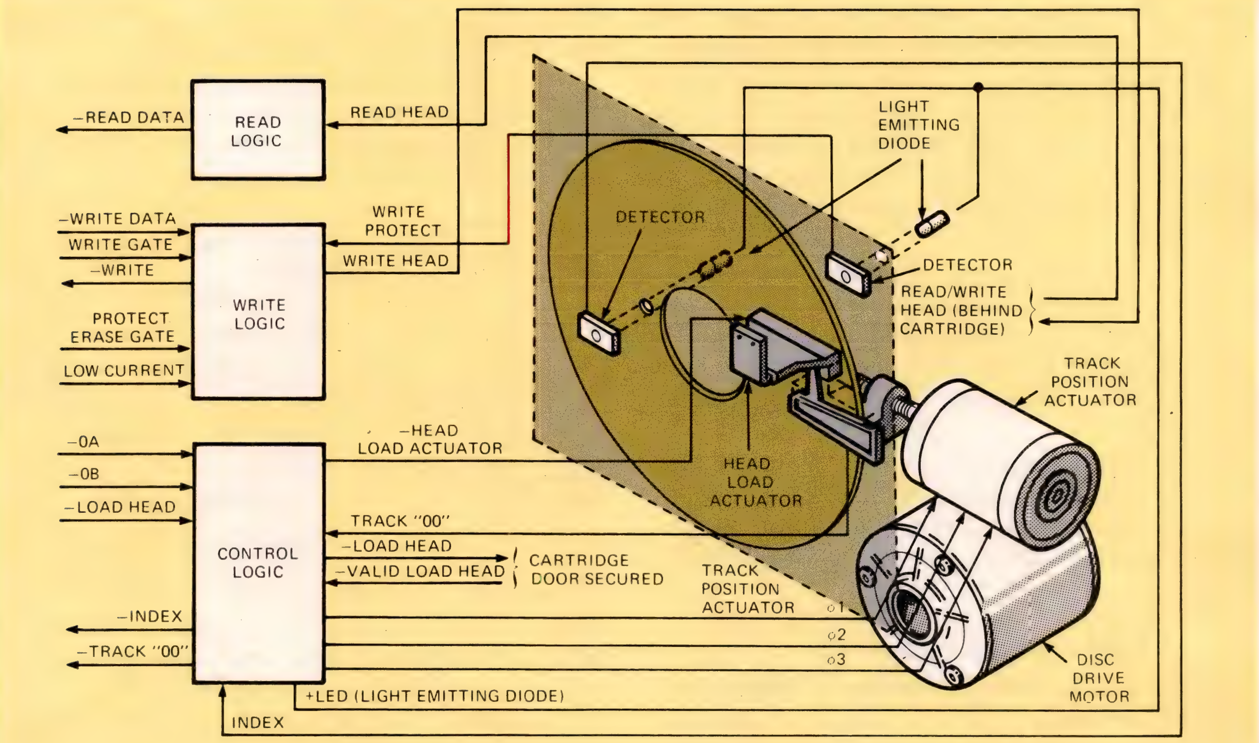
The flexible disc drive interfaces with the host system through the pc board housing the drive electronics. Signals present at this connection are TTL compatible.

The flexible disc media, a Mylar^R substrate coated with magnetic oxide, is contained in an 8-in. square jacket with a slit provided for head-to-disc contact. A cleaner-cushion material lines the jacket to help prolong the life of the disc. Through the wiping action created by loading the head, it absorbs tiny foreign surface particles. A protective and removable envelope then encloses the entire disc cartridge.

The read/write process is identical to that of magnetic tapes. Both use an oxide-coated mylar medium. Basically the head is a ring with gap and a coil wound around it. A current flowing in the coil produces a magnetic field across the gap, which in turn magnetizes the disc. The direction of current flow in the coil determines the direction of the magnetic flux in the ring gap. With two possible directions our ONE's and ZERO's are easily recorded. Reading data reverses the process. A flux reversal moving under the gap induces a voltage pulse in the coil, which registers as a ONE or ZERO.

Host system determines disc format

In order to be IBM 3740 compatible, a prescribed format (**Fig. 3a**) must be recorded on each of the disc data tracks (tracks 1 through 76). A



INTERFACE SIGNALS

MAJOR FUNCTIONAL ELECTRONIC BLOCKS

HEAD POSITIONING
HEAD LOADING DRIVER
READ AND WRITE ELECTRONICS
CLOCK AND DATA SEPARATION CIRCUITS
INDEX AND SECTOR DETECTION CIRCUITS
SAFETY SENSING CIRCUITS
WRITE PROTECTION

HOST CONTROLLER TO DRIVE

STEP IN/STEP OUT OR
STEP DIRECTION
HEAD LOAD
WRITE ENABLE
READ ENABLE
IBM COMPATIBLE UNITS INCLUDE
LOW CURRENT
ERASE ENABLE

DRIVE TO HOST CONTROLLER

COMPOSITE AND/OR SEPARATED CLOCK/DATA
INDEX/SECTOR
WRITE PROTECT
TRACK NUMBER
FILE UNSAFE

Fig. 1—General configuration of flexible disc drive will have minor changes depending on whether or not it is to be IBM compatible. Accompanying tables also may have minor additions.

prescribed format is required on track 00.

Fig. 3b shows a typical recording format used with the hard sector discs. Data can be organized in multiple records/track (sector) format or a single record/track (index) format. At the beginning of each record, 128 clock bits are required for mechanical tolerances and synchronization. Following the clock bits, a "data identifier" byte (specified by the user) is neccessary to recognize the start of data.

For ease of search and record verification, each data identifier block may be followed by an address byte(s) consisting of track and sector identification. In critical applications, the unit should read the address byte(s) to verify track and sector location before attempting a write operation. A read back check is recommended after the write operation.

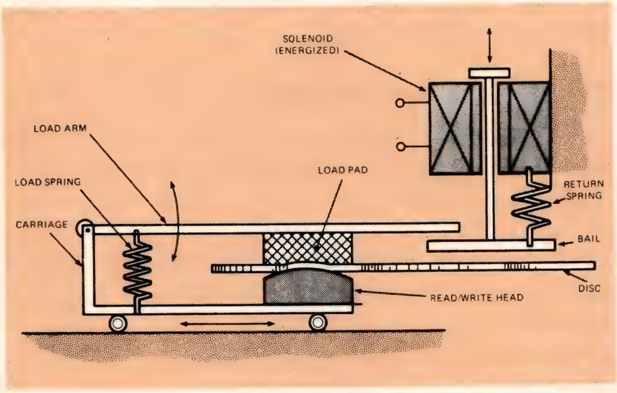


Fig. 2—Deformity of the disc is caused by head-to-disc to load pad compliance. This insures good contact to minimize read and write errors.

Using sector format, data is recorded with 32 records/track. Since each record or sector has the capacity to contain the same number of bits, bit density must increase from outer to inner tracks. Internal disc electronics do this automatically and interface with the host controller through an appropriate clock signal output.

Index format records only one record/track. Length of the data record is the only difference between index and sector format.

In hard-sectored discs, the number of sectors usually is constant as most of the work of sectoring is done by hardware. Soft-sectored discs allow any number of sectors/track with the added need of software or more complex hardware decoding of sectoring information.

Standardization isn't here yet

Not a great deal of effort has taken place in the area of standardization. The "defacto" standard created by IBM for their 3740 System is the media.

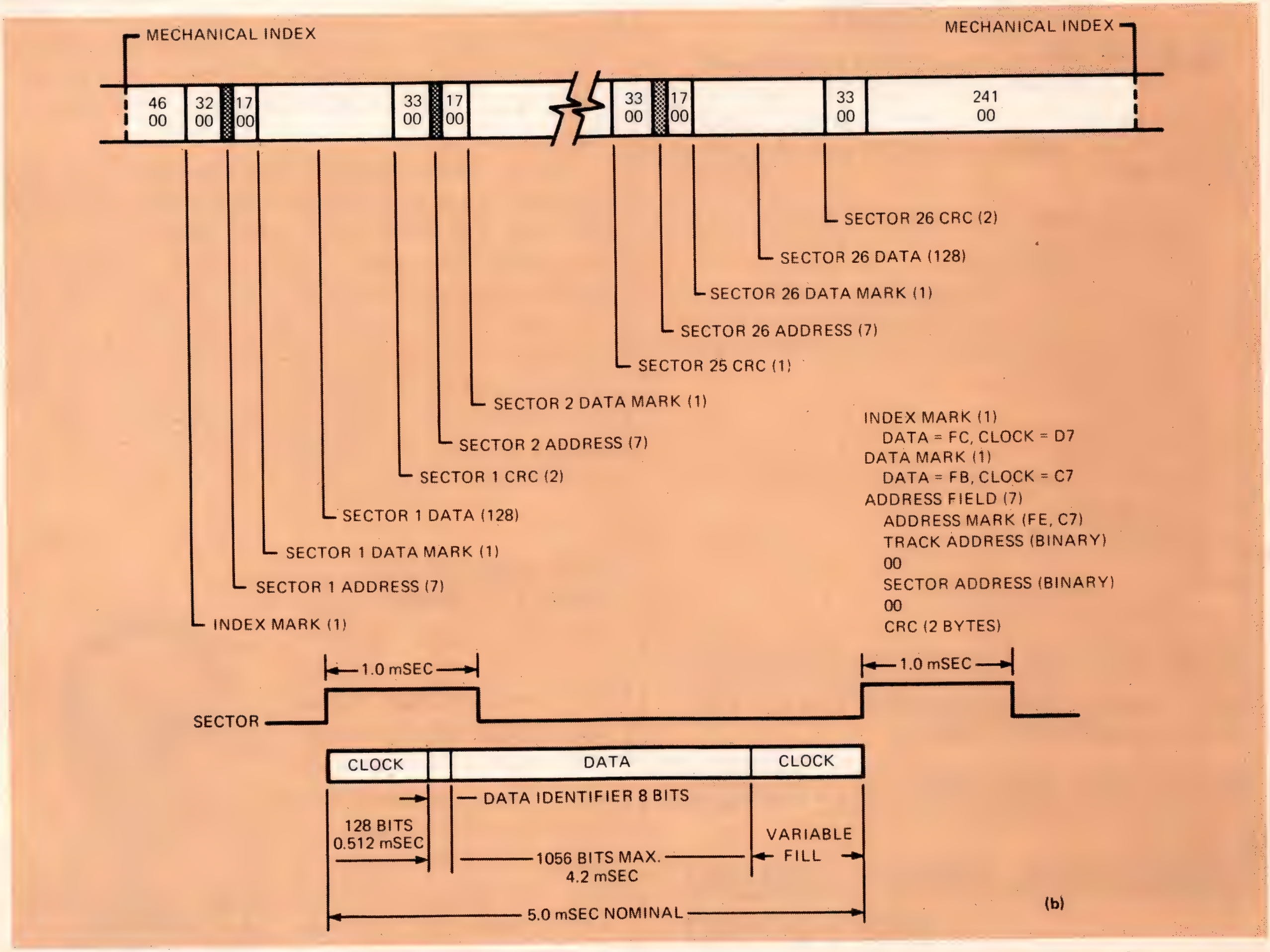


Fig. 3—Recording formats vary with manufacturers. One IBM type (**a**) is shown along with a hard sector format (**b**).

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For those using systems that interchange data with IBM 3740's, this format must be followed. Other IBM systems use different media and formats. Drive manufacturers producing IBM compatible drives also have failed to agree on a standard interface at the connector. Only pressure from the OEM users will bring the needed standardization about.

Again, no standardization exists in the nonIBM compatible drives. Both media and interface connector signals vary from drive to drive. Features, sales price, and manufacturer's reputation and capabilities are the predominate selection criteria in this group.

Toward a floppy future

The flexible disc's forte is its direct access function. Serial devices such as cassettes, cartridges and paper tape cannot supply this at any cost. Nor can they compensate for a lack of this function with significant cost savings. Direct access at the flexible disc's low price is doing for the μP/minicomputer industry what direct access devices did for larger general-purpose computer systems.

In the case of mini's and micro's, the flexible disc will accelerate the trend toward small, dedicated special-purpose systems and small general-purpose business systems. Growth in these market areas has already been spectacular. With the flexible disc attached, it could be explosive.

Future enhancements are inevitable. Already dual-drive packages and products with the ability to read and write both sides of the disc exist. Increased densities of recorded information, both in numbers of tracks and bits/track are sure to come. Dual-head units, that do not require operator intervention to read both disc sides, are being considered. Finally, the competitiveness of the market indicates a definite trend for reduced prices as the market shakes out its current and future requirements. □

Author's biography

Donald R. Reichel, engineering manager at Memorex Corp., Santa Clara, CA, is responsible for current flexible disc products. Previous to his six years with them, he was employed at IBM. Don received his BSME from the Univ. of Illinois and his MSME from USC. He has been granted one patent.

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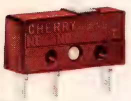
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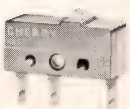
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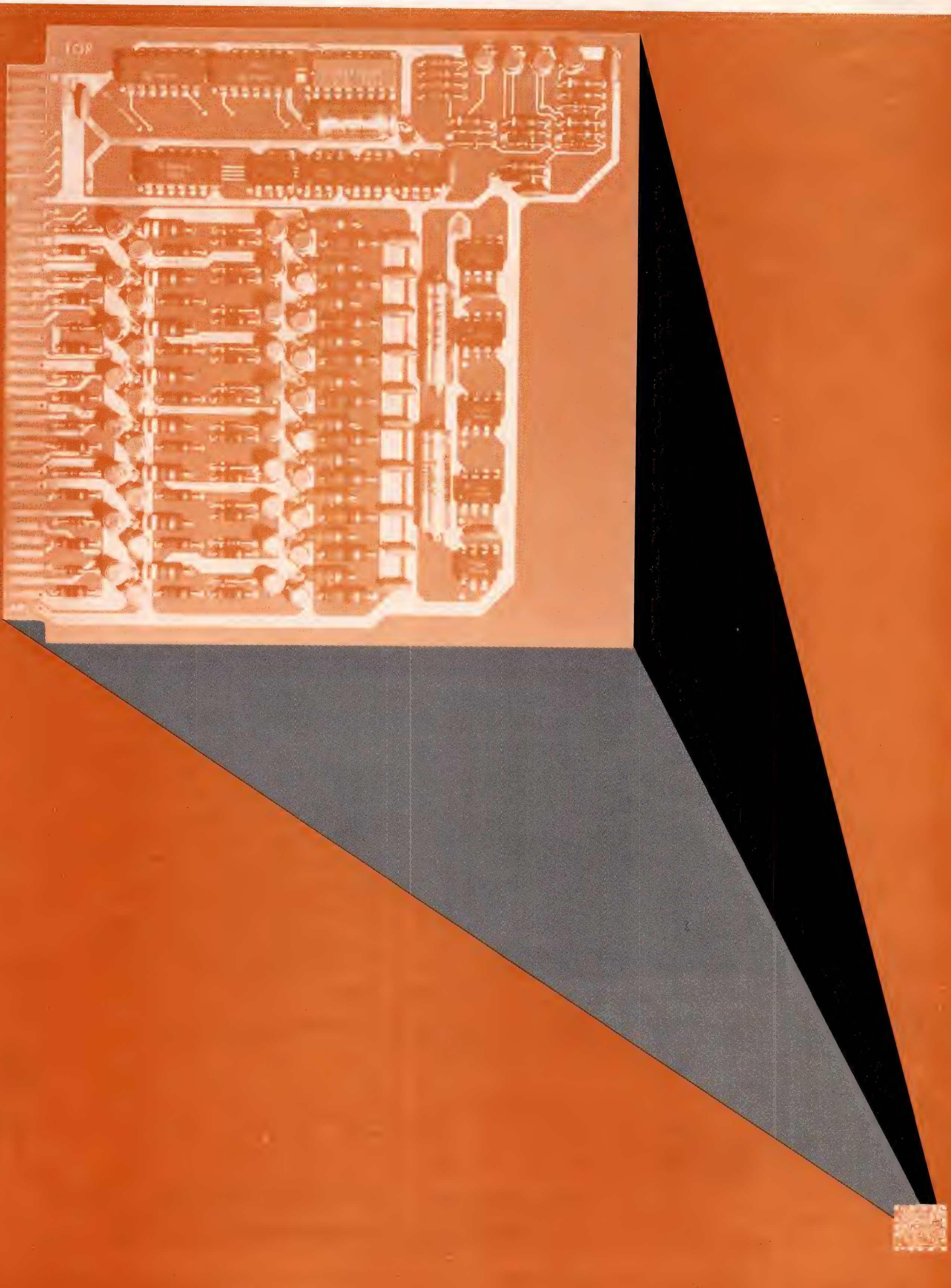

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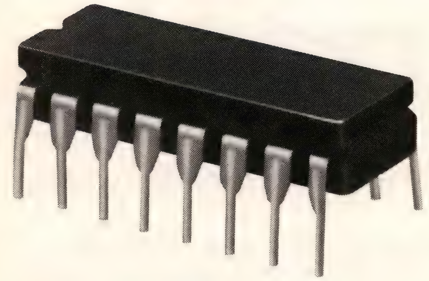

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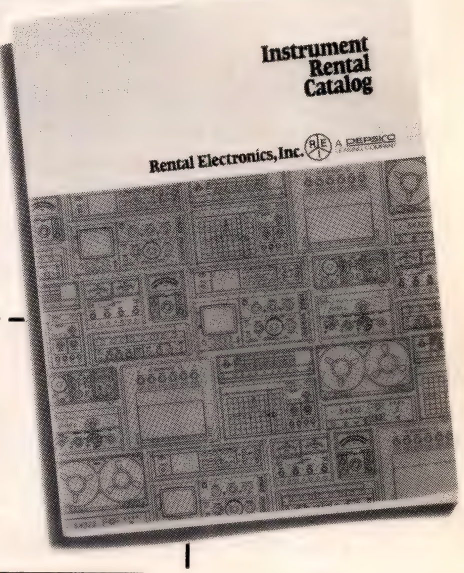

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Four make a family

The simplest circuit (**Fig. 1**) requires only two op amps and four matched resistors. This circuit is suited for applications where lower input impedance and lower frequency response are adequate. One of the amplifiers performs as a voltage-to-current converter; the other as a rectifying current-to-current converter.[1]

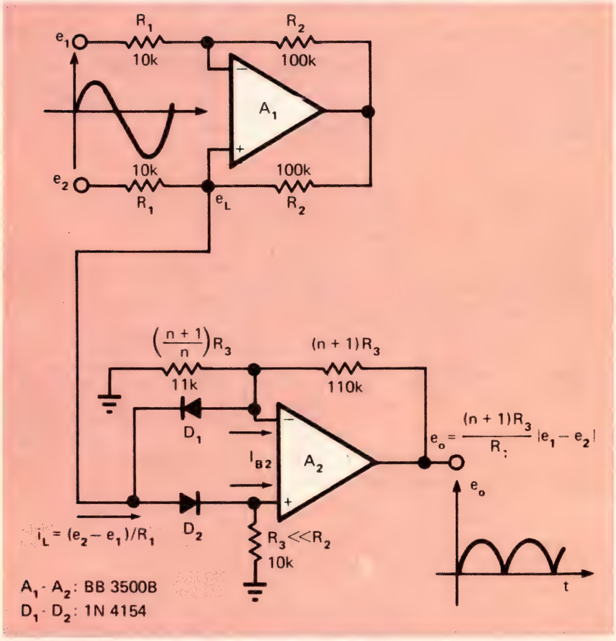


Fig. 1—Precision full-wave rectification of a differential voltage is achieved by transforming it to a current that is rectified and then reconverted to a voltage.

By converting the signal voltage to a current, we simplify accurate rectification because the rectifying diode voltage drops do not introduce error to a signal current. The conversion is performed by a differential-input voltage-controlled current source formed by A_1, R_1 and R_2. Input signal e_2 supplies current directly to the rectifier load, but this current is altered by the voltage, e_L, developed on the loading circuit. The R_2 positive feedback path supplies additional current to the rectifier circuit.

Controlling this current is the voltage developed by e_1 and e_L at the output of A_1. Fortunately, the effect of e_L on this current opposes the current supplied by e_2 and the two effects can be made to cancel. Cancellation occurs when the positive and negative feedback networks are matched as shown, and the current supplied to the rectifier is independent of the voltage it develops on the rectifier. Supplied to the rectifier is a current:

$$i_L = (e_2 - e_1)/R_1$$

To rectify this current we must diode gate it to whichever input of A_2 will result in a positive output voltage (**Fig. 2**). When the current is positive, D_2 is ON (**Fig. 2a**). The voltage developed on R_3 is amplified by a gain of n + 1, resulting in an output voltage of:

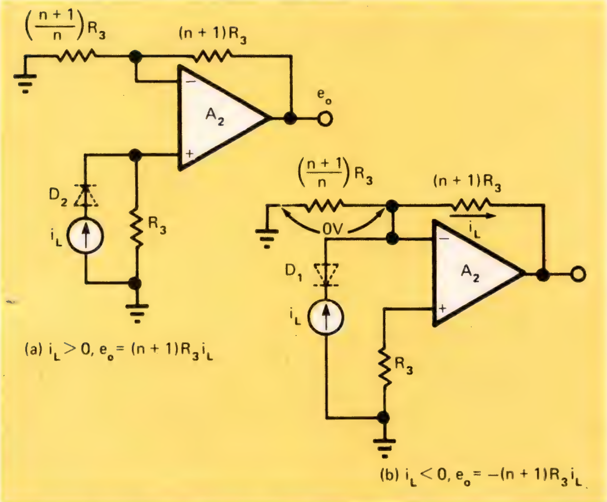
$$e_o = (n+1)\, R_3 i_L \text{ for } i_L > 0$$

When the current is negative, D_1 conducts it through the (n + 1) R_3 feedback resistor (**Fig. 2b**). None of the current is diverted by the other feedback resistor as A_2's inverting input now is essentially at ground potential. As a result, the output voltage developed is:

$$e_o = -(n+1)R_3 i_L \text{ for } i_L < 0$$

Note that this gain is the negative of that supplied to positive currents. Therefore, we have:

$$e_o = \frac{(n+1)R_3}{R_1} | e_1 - e_2 |$$



(a) $i_L > 0$, $e_o = (n+1)R_3 i_L$

(b) $i_L < 0$, $e_o = -(n+1)R_3 i_L$

Fig. 2—Rectification with the circuit of Fig. 1 results as the diodes switch opposite polarity currents to opposite amplifier inputs.

Limitations of design

Low-frequency performance of this precision rectifier is limited by the matching of the current-source resistors and by the dc errors of the op amps. Input resistance varies with the load resistance on the current source and is as low as R_1 from either input to ground. If we carefully match R_1 and R_2 we can maintain high current-source output resistance and high common-mode rejection. For perfect resistor matching, the output resistance approaches R_1 times the common-mode rejection ratio of the op amp, and the common-mode rejection of the current source equals that of the amplifier. The input offset voltage and input offset current of A_1 V_{os1} and I_{os1} produce a current source error of $I_{os1} + V_{os1}/R_1$. Generally, the total error current can be compensated by adjusting the amplifier null, unless R_1 is small.

Similarly, the input offset voltage of A_2 is readily removed. However, for this amplifier the effects of input bias currents, I_{B2}, cannot be removed by its null control. These currents offset the diode switching point from the signal zero crossing, and cause rectification to cease at low signal levels. Before D_2 will turn OFF, the current source must overcome the forward biasing effect of I_{B2}. D_1, though, is held OFF by the other input current.

To reduce this switching offset, we must develop a compensating current offset in the current source output. We accomplish this by adjusting the null control of A_1 while observing the rectification of a small signal.

As with most precision rectifiers, the high-frequency performance of the circuit of **Fig. 1** is limited by the ability of A_1 to rapidly drive the diodes ON and OFF at the zero crossing. At this transition, the output of the current source must swing a voltage equal to two diode drops, and during that swing the output signal is in error. The op-amp bandwidth or slewing rate determines the time required for this switching. However the time also depends upon the signal level.[1]

For the circuit of **Fig. 1** the switching time is increased greatly by loading the current source with a resistance much less than that of R_2. With $R_3 \ll R_2$, the positive feedback will be significantly less than the negative feedback, as needed to keep A_1 in a linear mode. However, with this condition, the amplifier output swing is greatly attenuated before reaching the diodes, requiring a swing many times the diode switching voltage. This increases the transition time. The net result is that ac error exceeds 1% at about 200 Hz.

High impedance—new design

When high input impedance is required at only one of the differential inputs, we can use the precision rectifier of **Fig. 3**. Here the impedance presented to one input is the high common-mode input impedance of A_1, while that at the other input remains equal to R_1. Bandwidth is also improved over the previous circuit because the rectifying diodes are driven by the full op-amp output. The time required for switching these diodes is still the principal bandwidth restriction as in the previous circuit. However, here the op amp only swings a voltage equal to two forward diode drops, thus extending the precision rectifier bandwidth to several kilohertz.

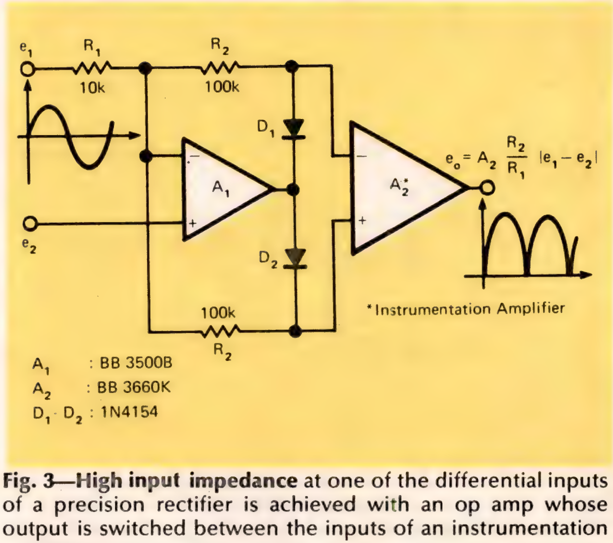


Fig. 3—High input impedance at one of the differential inputs of a precision rectifier is achieved with an op amp whose output is switched between the inputs of an instrumentation amplifier.

Rectification occurs as the diodes switch the op-amp output from one instrumentation amplifier input to the other. This reverses the polarity of the gain provided by the instrumentation ampflifier when signal polarity changes. Thus the output signal will always be positive.

Performance characteristics of this precision rectifier are determined primarily by resistor matching, the normal errors of the amplifiers and the switching offset common to precision rectifiers. Mismatch in the R_2 resistors results in unequal gain magnitudes for positive and negative signals and input signal range is limited by the minimum gain provided e_2 by A_1. Since minimum gain is two, the signal range for this input is limited to one-half that of the op-amp output. Total common-mode rejection ratio is A_1's ratio less R_1/R_2 times that of A_2. Some CMRR reduction results from the unequal source resistances presented to the inputs of both A_1 and A_2; however, a CMRR of 80 dB is feasible.

Error currents in the A_1's feedback paths bias the diodes ON or OFF when the differential input signal is zero. For the circuit of **Fig. 3** such error currents are due to the input offset voltage of A_1 and the input bias currents of both amplifiers. Until the input signal overcomes these error currents, there is a loss of rectification at low signal levels. To extend low level operation, the error currents can largely be compensated by adjustment of the A_1's offset control. This may increase the circuit output offset, but we can remove it via the null control of A_2.

Increased impedance all around

High impedance at both inputs of a differential-input precision rectifier can be achieved simply provided that a current output into a floating load is suitable. These characteristics are achieved using two op amps as in **Fig. 4**. This circuit eliminates the need for resistor matching. Both inputs present the high common-mode input impedance of an op amp. We can perform rectification by using a diode bridge to route the feedback current of A_2. This current is controlled precisely by the two op amps because their feedbacks determine the voltage on R.

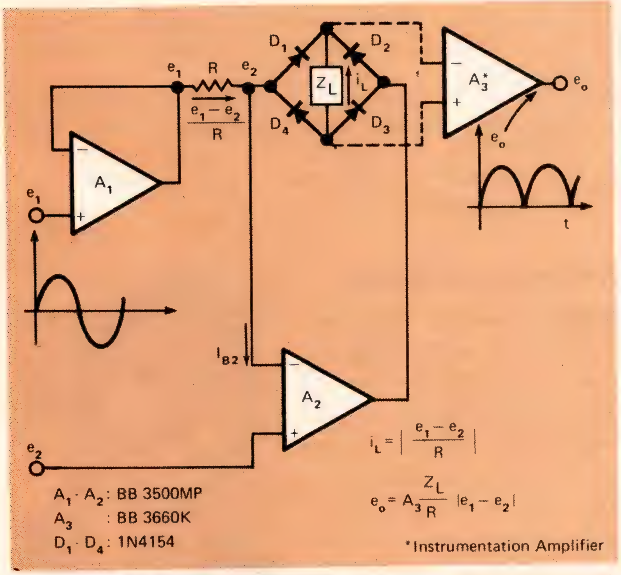


Fig. 4—High input impedance for a differential-input precision rectifier is provided by two op amps that produce a current output convertible to a voltage with an instrumentation amplifier.

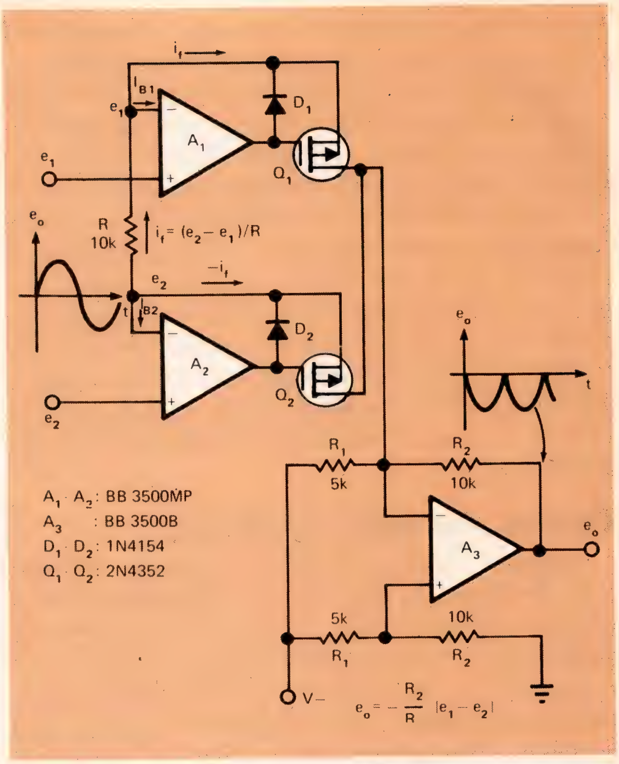


Fig. 5—A rectifying current source and a voltage-to-current converter form a differential-input precision rectifier with three op amps.

Alternately, a ground referenced voltage output can be produced using the instrumentation amplifier shown as A_3 in **Fig. 4**.

This approach uses the same amplifiers as a conventional precision rectifier preceded by an instrumentation amplifier, but resistor matching is less critical. While ratio error between R and Z_L affects gains for positive and negative signals equally, this is not the case for common precision rectifiers.

Circuit limitations include those of conventional follower-connected op amps, diode switching offset and speed limitation of diode switching.

Switching offset for **Fig. 4** results from a feedback error current of $I_{B2} + \Delta V_{os}/R$, where ΔV_{os} is the difference between the op-amp input offset voltages. Matched op amps, like those shown, minimize the ΔV_{os} error and its thermal drift. Adjusting the op-amp offset controls accomplishes removal of the error current and permits rectification of millivolt level signals.

Limitations to ac performance differ from those of conventional voltage followers in bandwidth and common-mode rejection. As previously discussed, the precision rectifier bandwidth is restricted by the speed with which A_2 can switch its feedback diodes. Because of this, bandwidth is reduced to a few kilohertz when using the general-purpose op amps shown. Common-mode rejection for the precision rectifier is, however, improved beyond those of its op amps. The common-mode errors of A_1 and A_2 tend to cancel so that a rejection of 100 dB is readily attained.

Ground plus high impedance

Another differential-input precision rectifier (**Fig. 5**) provides high input impedance and a ground-referenced voltage output using three op amps and four matched resistors. This circuit consists of a differential-input, rectifying, controlled-current source formed with A_1 and A_2, and a level shifting voltage-to-current converter formed with A_3.[3] Appropriate polarity feedback current is conducted to the output amp, while the other feedback current is absorbed by an op amp.

When $e_1 < e_2$, i_f is positive and will be conducted by Q_1 and D_2. There is no current flow in Q_2 as long as enhancement mode MOSFET's are used as in **Fig. 6**. The conducting MOSFET supplies current to the noninverting input of A_3. None of this signal current can flow in the R_1 resistor connected to Q_1 since the current in this resistor is fixed by the bias at the other input of A_3. To maintain equal voltages at its inputs, A_3 will conduct the signal current through its R_2 feedback resistor. This produces an output voltage of $-i_fR_2$. For $e_1 > e_2$, a current of $-i_f$ will flow through Q_2 to the output amplifier, and $e_o = i_fR_2$. In this way only positive signal currents are supplied to A_3 and the output voltage will be:

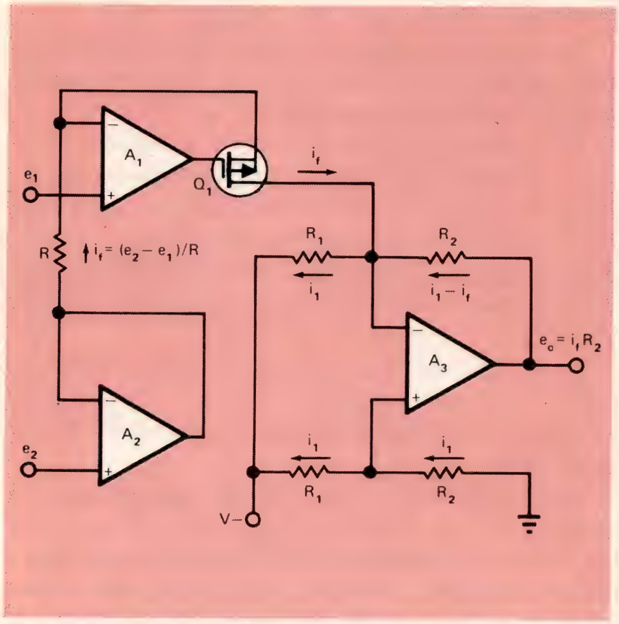


Fig. 6—For $e_2 > e_1$, the circuit of **Fig. 5** supplies current to the output amplifier thru Q_1 only.

$$e_o = \frac{-R_2}{R}|e_1 - e_2|$$

No output voltage is developed from the negative supply at the R_1 resistors, for this appears as a common-mode bias. That bias holds the inputs of A_3 at a low voltage to permit signal voltage swing on the MOSFET's.

Ubiquitous design factors again

Factors limiting the accuracy of the circuit of **Fig. 5** are similar to those that affect basic op amps. Switching offset and bandwidth limitations common to precision rectifiers are also present. Errors typical of voltage followers affect the operation of A_1 and A_2, and the usual difference amplifier errors are introduced by A_3.[2] Circuit switching is offset by error currents of $I_{B1} + \Delta V_{os}/R$ or $I_{B2} + \Delta V_{os}/R$ where ΔV_{os} is the difference between the offset voltages of A_1 and A_2. Once again, the error currents are reduced by the op-amp offset controls.

Bandwidth is more restricted for this circuit than for the preceding two, as A_1 and A_2 must swing a greater voltage at the switching transition. Now each amplifier must swing a voltage equal to a forward diode drop plus the threshold voltage of the MOSFET's. Since the CMR's of A_1 and A_2 tend to cancel, performance is improved. □

References

1. *J. Graeme, "Applications of Operational Amplifiers—Third Generation Techniques," McGraw-Hill, 1973.*
2. *G. Tobey, J. Graeme, L. Huelsman, "Operational Amplifiers; Design and Applications," McGraw-Hill, 1971.*
3. *D. Sheingold, "Nonlinear Circuits Handbook," Analog Devices, 1974.*

Author's biography

Jerald Graeme, with Burr Brown Research Corp. for nine years, is director of monolithic linear and analog/digital circuits. He received his MSEE from Stanford and has written and co-authored numerous technical articles as well as several op-amp applications books. A member of Tau Beta Pi, Jerald resides in Tuscon, AZ.

Electronic Component
Leadtime Index

January 1975

	LEADTIME IN WEEKS		
	MIN.	MAX.	TREND
CAPACITORS			
Ceramic	5	15	↓
Electrolytic			
aluminum	7	17	↓
tantalum	8	18	↓
Film	6	11	=
Mica	7	15	↓
Paper	7	13	↓
Trimming	4	9	=
CONNECTORS			
Coaxial	6	12	↓
Multipin circular			
high-density	11	16	↓
standard	7	11	=
Printed-circuit	5	10	↓
Rack & panel	4	8	↓
INTEGRATED CIRCUITS			
DTL	5	12	↓
ECL	4	10	↑
TTL	5	10	↑
MOS	4	10	=
CMOS	5	13	↑
Op amps (monolithic)	4	8	↑
Voltage regulators	3	7	↓
PACKAGED CIRCUITS			
Digital logic	6	12	↓
Op amps (hybrid & discrete)	7	12	↓
PRINTED CIRCUITS			
Multilayer	6	10	↑
Two-sided	5	6	↓
RELAYS			
Crystal-can	9	12	↓
Reed	8	10	↑
General-purpose	5	9	↓
Stepping	7	10	↓
Telephone	8	10	=
Solid-state	6	9	↓

	LEADTIME IN WEEKS		
	MIN.	MAX.	TREND
RESISTORS, FIXED			
Composition	3	10	↑
Dep.-carbon & carbon-film	7	17	↓
Metal-film	6	15	↓
Wirewound	6	11	↓
RESISTORS, VARIABLE			
Nonwirewound			
nonprecision	3	7	↓
precision	4	9	↓
Trimmers	3	8	↓
Wirewound			
nonprecision	3	8	↓
precision	4	9	↑
trimmers	4	8	↓
SEMICONDUCTORS			
FET's	2	5	↓
Power rectifiers	4	9	↓
Power transistors	6	11	↓
SCR's & triacs	7	13	↑
Silicon switching transistors	4	9	↓
Switching diodes	6	13	↓
Zeners	3	8	↓
SWITCHES			
Lighted pushbutton	7	13	↓
Pushbutton	5	9	↓
Rotary	6	10	↓
Snap-action	5	7	↓
FANS & BLOWERS	5	15	↓
FRACTIONAL H.P. MOTORS	15	30	↓
WIRE & CABLE	5	16	↓
PANEL METERS	7	13	↓
LIGHT-EMITTING DIODES	3	7	=
READOUTS & DISPLAYS	4	5	↓

Leadtime index information is derived from a questionnaire completed by a select group of Electronic Purchasing Magazine's readers: purchasing managers, buyers, distributors and manufacturers. To allow for printing, publishing and mailing time, the questionnaires must be submitted at least two months prior to publication—leadtimes are therefore based on recent, but not absolutely current, figures. The leadtime figures shown are averages and represent the amount of time required if a vendor had to allocate manufacturing time to your request. Naturally, in each category popular items may be more scarce than less popular ones. Likewise small orders might be processed faster than large ones.

Classical minicomputer system moves parts for minicars

"Off-the-shelf" business-oriented mini's eliminate clerical and accounting bottlenecks that lead to paralyzing inefficiencies.

Brian Wald, Interpart, Inc.

Small businesses don't need an IBM 370 to solve their difficult accounting and control problems. In many applications, a minicomputer will do quite nicely. A classic example of this is the task of maintaining current bookkeeping and reporting requirements of Interpart, Inc.

How does your company grow?

In two years Interpart has grown from a manufacturer and distributor of relatively few race-developed parts to a veritable supermarket of performance parts and accessories for minicars and motorcycles marketed in the United States.

Early in the company's development, it was evident that powerful financial, logistic and decision-making control was necessary. Million dollar computer-based management systems provide this control in big, diversified companies, but Interpart certainly could not compete in that class. Instead, they turned to Basic/Four Corp. of Irvine, CA for help.

Interpart's complete business computer system consists of the controller and disc storage unit (**not shown**); the operator station with keyboard and display terminal (**left**); and the printer unit (**right**).

...With a computer!

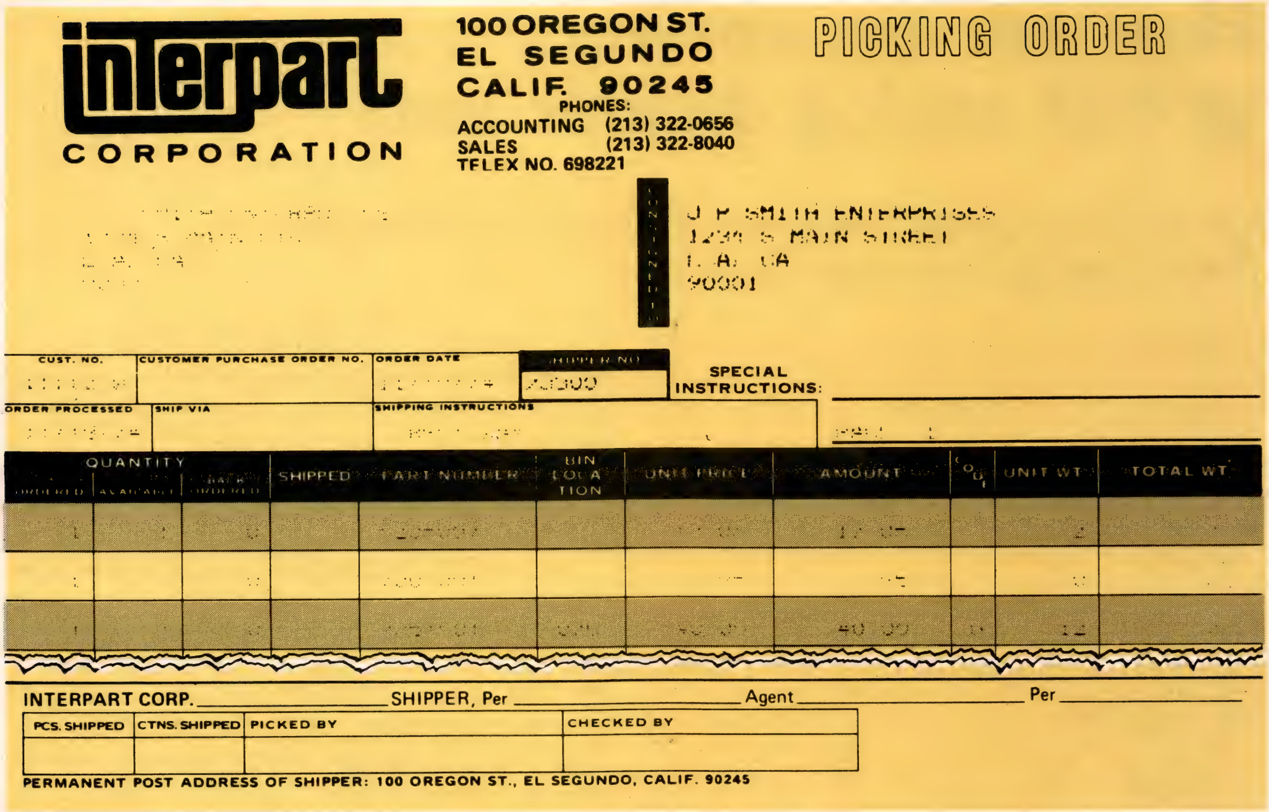
Basic/Four solved Interpart's problem with a complete minicomputer-based business system tailored specifically for small and medium-size organizations. This system, less programs, leases for about $1000/month including maintenance.

Use of this system has done away with literally dozens of clerical and bookkeeping tasks and countless files of documents. Just about every business task is done automatically by the computer using data entered from a single source document. That document is the "pick list" used to fill customer orders from inventory shelves.

The system begins with an order from any one of Interpart's 350 distributor warehouses. An operator at the typewriter keyboard then enters the order into the computer. When this is done, the computer automatically arranges the order in the format of a pick list, which is printed out. The list is arranged so that the parts chaser can simply walk down one aisle after another picking parts from the bins in the listed order.

System saves time, money and men

Interpart handles, on the average, about 300 pick lists per day. The tasks necessary for fulfilling these lists are executed by a single operator and two parts chasers. This gives a good indication of the contribution the computer makes to relieving the office work load. To do the task manually would require four or five additional clerks. Without the efficiency of the computer-



interpart CORPORATION

100 OREGON ST.
EL SEGUNDO
CALIF. 90245
PHONES:
ACCOUNTING (213) 322-0656
SALES (213) 322-8040
TELEX NO. 698221

PICKING ORDER

[illegible]

J P SMITH ENTERPRISES
1234 S MAIN STREET
L. A. CA
90001

CUST. NO.	CUSTOMER PURCHASE ORDER NO.	ORDER DATE	SHIPPER NO.
[illegible]		[illegible]	[illegible]

ORDER PROCESSED	SHIP VIA	SHIPPING INSTRUCTIONS
[illegible]		[illegible]

SPECIAL INSTRUCTIONS: [illegible]

QUANTITY ORDERED	QUANTITY AVAILABLE	QUANTITY BACK ORDERED	SHIPPED	PART NUMBER	BIN LOCATION	UNIT PRICE	AMOUNT	% OFF	UNIT WT	TOTAL WT
[illegible]	[illegible]	[illegible]		[illegible]		[illegible]	[illegible]		[illegible]	
[illegible]		[illegible]		[illegible]		[illegible]	[illegible]		[illegible]	
[illegible]		[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	

INTERPART CORP.____________ SHIPPER, Per ____________ Agent ____________ Per ____________

PCS. SHIPPED	CTNS. SHIPPED	PICKED BY	CHECKED BY

PERMANENT POST ADDRESS OF SHIPPER: 100 OREGON ST., EL SEGUNDO, CALIF. 90245

The "picklist" is the basic source document used to enter data in the computer.

sequenced pick lists, the number of parts chasers would also be much higher. In addition, however, a manual system could never provide the additional services that the computer performs routinely and automatically.

For example, after updating, the computer prepares a bill of lading with shipping weight by unit and by totals shipped. The computer also automatically prepares invoices for customer orders and maintains the back order shipping list for each customer.

While carrying out the order fulfillment function, the computer does inventory control and accounts receivable. Additionally, the computer maintains, in its memory file, an inventory book that can be printed out at any time. The same program that accomplishes this also computes a minimum and maximum number of parts to be kept in stock based on sales history for that part.

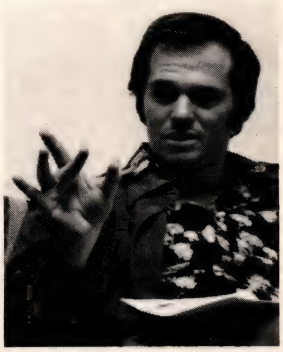
The computer memory retains each purchase order in a separate file with an expected receiving date. This information, combined with accounts receivable, permits a day-by-day analysis of cash flow. All bills due are paid automatically at the end of the week by the computer unless excepted.

In addition to the jobs already mentioned, the Basic/Four business system maintains the company payroll. Yet, with all this activity, the minicomputer operates only four and a half hours a day. This is extremely important to a budget-conscious firm with a burgeoning future.

Potential applications unlimited

The number of routine reports that can be extracted from a minicomputer accounting and control system is limited by little more than the needs of the organization and the imagination of management. The same data used to prepare invoices, for example, can yield sales analyses by distributor, geographic region, product category, or almost any other logical breakdown. ☐

Author's biography



Brian H. Wald, Executive Vice President of Interpart Inc., received his undergraduate degree in Finance and Real Estate Management from USC and a Doctor of Law from UCLA. He is a member of the California Bar. Before helping to form Interpart, he was president of Bel Air Foods, a food processing and international food distribution firm.

Here are the answers to our analog divider quiz

We said you can go a long way with a little information.
But did you go in the right direction?

ANSWERS

1. b
2. c
3. b
4. c
5. b
6. a
7. a
8. d
9. I. c
   II. a
   III, IV. b, d
10. I. a
    II. c
    III. d
    IV. b
11. I. a
    II. b
    III, IV. c, d
12. d
13. c
14. c

Back in the introductory comments prefacing the quiz, we instructed the readers to select the "most nearly" correct answer. A qualification such as "most nearly" infers the possibility of debate concerning the correctness of the answers. To that end, we offer the following commentary on our selections.

1. To obtain a positive output from the inverting op amp with X and Y positive, the net output current of the "multiplier block" must be in the negative sense. As a multiplier or divider then, $Z = -(-XY/10)$. Therefore, as a divider, $E_o = Y = 10Z/X$.

2. For the divider circuit to perform stably, the "multiplier block," which is the feedback path of the inverting op amp, must have positive sense. The feedback gain, which is controlled by X, is negative for positive X. Therefore, X must be negative in polarity. For example, when Z = +5V and X = −5V, $E_o = 10\times(5)/(-5) = -10V$; when Z = −5V and X = −5V, $E_o = 10\times(-5)/(-5) = +10V$.

3. Two factors affect the response of the divider to the ac input signal. The low-frequency gain operating on the input signal is (10/X). If the magnitude of X is 1V dc and the gain is 10, the 0.2V p-p signal would be amplified to 2V p-p. However, the bandwidth of an inverted-multiplier divider, having a single-pole rolloff, is inversely proportional to the gain. For a gain of 10, the multiplier's 3-dB bandwidth is reduced from 300 to 30 kHz. Therefore, the output magnitude is reduced to (0.7)(2) = 1.4V p-p.

4. With the inputs at zero, the multiplier output offset can be viewed as an input voltage that is effectively in series with the Z input. In the divider connection, this voltage is multiplied by the gain magnitude, 10/X. Therefore, $E_o = 0.01V \times (10/1) = 100$ mV.

Incidentally, the multiplier output noise is also magnified by 10/X in the divide mode, subject to bandwidth limitations (see comments in question 3).

5. The offset drift, like the offset in question 4, can be considered as an effective Z_{os} drift, multiplied by the gain, 10/X. Therefore, the drift equals (1 mV/°C)(70° − 25°)(10/1) = 450 mV.

6. If the device has been zeroed as a multiplier (as in the case of a pre-trimmed device), the errors are already small. In this case, the procedure of (**a**) will give satisfactory results. However, some interaction between the adjustments usually takes place. If the device has to be adjusted from scratch, none of these dc procedures is as satisfactory as a procedure using an oscilloscope crossplot.[3] In any event, here is a description of the functions of the adjustments listed in the table:

(1) adjusts the output offset (Y_{os}) of the divider; full-scale denominator voltage minimizes the effect of input offset, Z_{os}.

(3) adjusts numerator offset, Z_{os}. Small denominator magnitude increases sensitivity to Z offset and eases adjustment. The actual value of X is immaterial as long as it is the correct order of magnitude.

(4) adjusts the gain after the input and output offsets have been zeroed. Use the largest value of X in the denominator (and numerator) for minimum sensitivity to X_{os}.

(2) adjusts X offset to maintain constant gain, i.e., $Z_{low}/(X_{low} + X_{os}) = Z_{high}/(X_{high} + X_{os}) \approx Z_{high}/X_{high}$. This adjustment is best accomplished with equal magnitudes of both numerator and denominator decreased to a small fraction of full scale.

7. Theoretical full scale occurs when the magnitude of Z is maximum and the magnitude of X is minimum. It is, therefore, 10 × 10/0.1 = 1000V.

8. Overrange must be prevented by controlling the inputs. Hence, X should be amplified by 10, and Z should be attenuated by 10. Note that when the inputs are scaled for 10V maximum output, the minimum output will be 10 mV.

9. (I) The bandwidth of the "linearized 2-quadrant divider" is fairly constant over a 100:1 denominator range; at very low values, it decreases in proportion to the denominator.

(II) Most general purpose variable-transconductance multiplier/dividers have fairly wide bandwidth when used as multipliers or as dividers with "gain" (10/X) of unity. But bandwidth is inversely proportional to gain (directly proportional to denominator), and (II) runs out of "gas" rather quickly.

(III and IV) The high accuracy pulse-modulation multiplier and the log-antilog divider usually have much less bandwidth than I and II; their bandwidth decreases in proportion to denominator voltage.

10. (I) The inverted-multiplier divider using a "1%" multiplier will have the highest error and lowest dynamic range of the four types, for the reasons indicated in questions 4 and 5.

(II) Among 2-quadrant types, the "linearized 2-quadrant variable-transconductance" divider maintains low error over the widest range of denominator voltage.

(III) The log-antilog divider maintains the lowest error over the widest range of denominator in 1-quadrant operation.

(IV) The high accuracy pulse-modulated multiplier, used as an inverted-multiplier divider, has the best accuracy over a 3:1 dynamic range. It becomes worse, though, than II and III beyond a 10:1 dynamic range (it also tends to be the most expensive).

11. (I) The "1%" inverted-multiplier divider has the greatest drift over the narrowest dynamic range.

(II) The high accuracy pulse-modulated multiplier, used as an inverted-multiplier divider, has lower drift error than "1%" types, but the drift increases with decreasing denominator voltage.

(III and IV) The specialized dividers are the most stable.

12. Impedance has two components: magnitude and phase. Since magnitude depends on the ratio of the amplitudes of the signals, what must be divided is the measure of their amplitudes, not the signals themselves. The measure may be peak, average or rms. If the signals themselves are divided, the results will be meaningless, because ordinary dividers will not work at all when the denominator changes sign. Even if a "4-quadrant divider" is built (employing switching), the problem of the pole in the vicinity of zero denominator still exists. In addition, we're computing $|V_E/V_I|$ secant $\Theta/(1 + \cot \omega t \tan \Theta)$ instead of the ratio of the amplitudes.

If the phase component of impedance is desired, one of a number of phase-metering circuits could be used.

13 and 14. Fig. 7 is a useful circuit for neutralizing the inherent nonlinearity of the unbalanced Wheatstone bridge. At the same time, it will compensate for variations of the bridge supply voltage. If the bridge nonlinearity is neutralized, there is no reason to restrict the amplitude of α (which is normally kept small to minimize the effects of bridge nonlinearity).

Two of the primary benefits are a reduced gain requirement and minimization of noise. Since the denominator is not likely to change by more than about 2:1, it would appear that any type of divider, including inverted-multiplier, might be used. It should be noted, however, that the divider nonlinearity becomes the principal source of error in this configuration. There is no advantage to compensating for bridge supply variations if it turns out that K_D is less stable than V_R. Therefore, a good, stable linear divider should be used.

Fig. 1

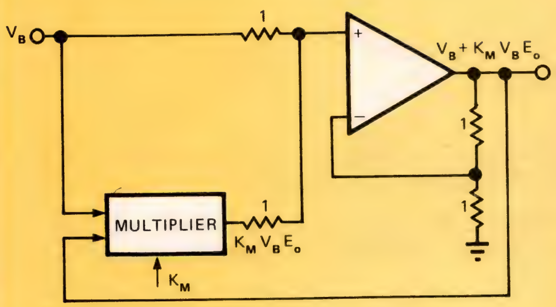


Fig. 1 shows a linearizing circuit of comparable simplicity. Using a multiplier instead of a divider to furnish an implicit compensation for bridge nonlinearity, it is characterized by the equation:

$$E_o = V_B + K_M V_B E$$

where K_M is adjusted to equal $1/KGV_R$, and E_o equals $KGV_R(\alpha/M)$. This configuration is inherently more linear than the divider scheme, because the multiplier supplies just the correction rather than the entire output. The scheme does, however, lack the correction for variations in V_R. If a multiplier is to be used at all, this circuit is preferred to the inverted-multiplier divider. □

1975

Caravan

The EDN Eighth Annual Mobile Trade Show will be on the road in January-March 1975.

This unique "Electronic Components Show" will exhibit products and capabilities of these participating companies:

AVX CERAMICS, Division of Avx Corporation
BURNDY CORPORATION
C & K COMPONENTS INC.
C. P. CLARE & COMPANY
DATEL SYSTEMS, INC.
GARRY MANUFACTURING COMPANY
GRAYHILL, INC.
T-BAR INCORPORATED, SWITCHING COMPONENTS DIVISION
WOVEN ELECTRONICS

EDN / 221 Columbus Ave. / Boston, Mass. 02116

We may be visiting your city—or perhaps your own plant site. Watch for the detailed tour schedule in our next issue.

1975 EDN ELECTRONIC COMPONENT — MOBILE TRADE SHOW TOUR ITINERARY — January 27, 1975 through April 2, 1975

DATE	TIME	SITE
1/17 A.M.	Monday 9-11:30	McDONNELL DOUGLAS, Lambert Street, St. Louis Airport, St. Louis, Missouri—Enter Brown Road, Gate #32. Van park near Building #33—Others use nearby visitors parking.
1/27 P.M.	Monday 2-4:30	McDONNELL DOUGLAS, Brown Road, St. Louis, Missouri Enter Gate #107, Brown Road. Van park at rear of Building #107—Others use nearby visitors parking.
1/28 A.M.	Tuesday 9-12:00	*EMERSON ELECTRIC, 8100 West Florissant, St. Louis, Missouri
1/29 A.M.	Wednesday 9-11:30	*WESTERN ELECTRIC, 777 North Blue Parkway, Lee's Summit, Missouri—Enter Truck Gate, Chipman Road. Van park at Receiving Dock Driveway—Others use visitors parking.
1/29 P.M.	Wednesday 2-4:30	*BENDIX CORPORATION, 2100 East Bannister Road, Kansas City, Missouri—Van park at Purchasing Building—Others use visitors lot.
1/30 A.M.	Thursday 9-12:00	*NATIONAL CASH REGISTER, 3817 North Rock Road, Wichita, Kansas—Van park in West parking lot—Others park near van.
1/31 A.M.	Friday 9-12:00	HONEYWELL INFO SYSTEMS, 4000 N.W. 39th Expressway, Oklahoma City, Oklahoma—Van park at Building #1 Others use visitors lot.
2/3 A.M.	Monday 9-11:30	*RECOGNITION EQUIPMENT, 2701 East Grauwler Road, Irving, Texas—Van park near Employee Entrance adjacent to Employee Parking Lot—Others park near van.
2/3 P.M.	Monday 2-4:30	E-SYSTEMS, 9314 West Jefferson, Grand Prairie, Texas—Van park at Building #198 Visitors Lot—Others park near van.
2/4 A.M.	Tuesday 9-11:30	&COLLINS RADIO, 1200 North Alma Road, Richardson, Texas
2/4 P.M.	Tuesday 2-4:30	*E-SYSTEMS, 1200 Jupiter Road, Garland, Texas—Van park adjacent to walkway and curb at south end of Building #551 Others use visitors lot #551.
2/5 A.M.	Wednesday 9-12:00	*TEXAS INSTRUMENTS, 135000 North Central Expressway, Dallas, Texas
2/6 A.M.	Thursday 9-11:30	TEXAS INSTRUMENTS, 12203 S.W. Freeway, Stafford, Texas Van park at DSD Building—Others park opposite side of street at Front Lobby.
2/6 P.M.	Thursday 2-4:30	SCHLUMBERGER TECHNOLOGY, 5000 Gulf Freeway, Houston, Texas—Van park at East Engineering & Cafeteria—Others park at East Employment Guard Gate.
2/7 P.M.	Friday 2-4:30	*DATA POINT, 9725 Data Drive, San Antonio, Texas—Van park in Southwest Parking Lot, outside Purchasing Lobby Others park near van.
2/10 A.M.	Monday 9-11:30	*IBM CORPORATION, 11400 F.M. Road 1325, Austin, Texas Van park in Visitors Lot in front of Main Gate—Others use north end of Visitors Lot.
2/10 P.M.	Monday 2-4:30	&TRACOR INC., 6500 Tracor Land, Austin, Texas
2/11 A.M.	Tuesday 9-12:00	&TEXAS INSTRUMENTS, 12501 Research, Austin, Texas
2/12	Wednesday	DRIVE DAY
2/13 A.M.-P.M.	Thursday 8-3:00	*MOTOROLA, INC., 8201 East McDowell Road, Scottsdale, Arizona—Van park at Receiving Security Guard Station Others park near van.
2/14 A.M.	Friday 9:30-12:00	*SPERRY FLIGHT SYSTEMS, 21111 North 19th Avenue, Phoenix, Arizona—Guard at South Gate will direct for parking.
2/14 P.M.	Friday 2-4:30	&HONEYWELL INFO SYSTEMS, 13430 North Black Canyon Highway, Phoenix, Arizona
2/17 A.M.	Monday 9-11:30	&GENERAL DYNAMICS, 3302 Pacific Highway, San Diego, Calif.
2/17 P.M.	Monday 2-4:30	&GENERAL DYNAMICS, 5001 Kearney Mesa, San Diego, Calif.
2/18 A.M.	Tuesday 9-11:30	&TELEDYNE RYAN AERONAUTICS, 2701 Harbor Drive, San Diego, Calif.
2/18 P.M.	Tuesday 2-4:30	&NAVAL ELECTRONICS LAB, 271 Catalina Boulevard, San Diego, Calif.
2/19 A.M.	Wednesday 9-12:00	&BURROUGHS, 25725 Jeronimo Road, Mission Viejo, Calif. Van park in visitors lot in front of building—Others park near van.
2/20 A.M.	Thursday 9-11:30	*PHILCO FORD CORPORATION, Ford Road, Newport Beach, Calif. Van park at Environmental Test Building—Others use parking lot, West Gate.
2/20 P.M.	Thursday 2-4:30	&VARIAN DATA MACHINES, 2722 Michelson Drive, Irvine, California (To be confirmed)
2/21 A.M.	Friday 9-11:30	*NORTHRUP CORPORATION, 500 East Orangethorpe, Anaheim, California—Van park adjacent to Building Y-2—Others park near van.
2/21 P.M.	Friday 2-4:30	&ROCKWELL INTERNATIONAL, 3370 Miraloma Avenue, Anaheim, California—Van park in parking lot at 3rd and Coronado—Others park near the van.
2/24 A.M.	Monday 9-11:30	&GENERAL AUTOMATION, 1055 South East Street, Anaheim, California
2/24 P.M.	Monday 2-4:30	&BECKMAN INSTRUMENTS, 2400/2500 Harbor Road, Fullerton, California (To be confirmed)
2/25 A.M.	Tuesday 9-11:30	*HUGHES AIRCRAFT, 1901 West Malvern Avenue, Fullerton, California—Van park between Building #601 & #604 Others park in visitors lot, Gate #6.
2/25 P.M.	Tuesday 2-4:30	XEROX CORPORATION, 600 East Bonita Avenue, Pomona, Calif. Guard at 600 East Bonita will direct van—Others park in parking lot.
2/26 A.M.	Wednesday 9-11:30	&GENERAL DYNAMICS, 1675 West Mission Boulevard, Pomona, California
2/26 P.M.	Wednesday 2-4:30	HOFFMAN ELECTRONICS, 4323 North Arden Drive, El Monte, California—Van park in south parking lot near door #19 Others park in vendors lot.
2/27 A.M.	Thursday 9-11:30	XEROX CORPORATION, 300 North Halstead, Pasadena, Calif. Van enter at 300 North Halstead, Vern Smith will direct for parking—Others same directions.
2/27 P.M.	Thursday 2-4:30	&BELL & HOWELL, 300 Sierra Madre, Pasadena, California
2/28 A.M.	Friday 9-11:30	*BURROUGHS CORPORATION, 460 Sierra Madre, Pasadena, California—Van park inside fence between Main Gate and Credit Union—Others use visitors lot.
2/28 P.M.	Friday 2-4:30	&LITTON SYSTEMS, 5500 Canoga Avenue, Woodland Hills, California
3/3 A.M.	Monday 9-11:30	&SINGER COMPANY, 2350 Washington, San Leandro, California
3/3 P.M.	Monday 2-4:30	AMPEX CORPORATION, 401 Broadway, Redwood City, California—Van park in parking lot at rear of Corporation Headquarters—Others park near van.
3/4 A.M.	Tuesday 9-11:30	&HEWLETT PACKARD, 1501 Page Mill Road, Palo Alto, Calif.
3/4 P.M.	Tuesday 2-4:30	PHILCO FORD, 3939 Fabian Way, Palo Alto, California—Van park at Building #1, North side parking area—Others park near van.
3/5 A.M.	Wednesday 9-11:30	VIDAR CORPORATION, 77 Ortega Avenue, Mountainview, California—Van park at southeast corner of parking lot Others park near van.
3/5 P.M.	Wednesday 2-4:30	&INFORMATION STORAGE SYSTEMS, 10435 North Tantau, Cupertino, California
3/6 A.M.	Thursday 9-11:30	*HEWLETT PACKARD, 11000 Wolfe Road, Cupertino, California Van park at North side of parking lot, corner of Homestead and Wolfe Road, rope area—Others park near van.
3/6 P.M.	Thursday 2-4:30	*HEWLETT PACKARD, 5301 Stevens Creek Boulevard, Santa Clara, California—Van park at Building #51, west side—Others use visitors lot.
3/7 A.M.	Friday 9-11:30	MEMOREX, Central and San Tomas, Santa Clara, California Van park in general parking area, roped area—Others park near van.
3/7 P.M.	Friday 2-4:30	&ITEK CORPORATION, 645 Almandor, Sunnyvale, California* (To be confirmed)
3/10 A.M.	Monday 9-11:30	BURROUGHS CORPORATION, 6300 Hollister Avenue, Goleta, California—Van park at rear of north parking lot—Others use vendors parking lot.
3/10 P.M.	Monday 2-4:30	TELEDYNE SYSTEMS CORPORATION, 19601 Nordhoff, Northridge, California—Van park in parking lot at north side of building—Others park near van.
3/11 A.M.	Tuesday 9-11:30	SINGER COMPANY, 833 Sonora Avenue, Glendale, California Van park in visitors lot at Main Administration & Employment area—Others park near van.
3/11 P.M.	Tuesday 2-4:30	&CONTROL DATA CORPORATION, 2815 West El Segundo Boulevard, Hawthorne, California
3/12 A.M.	Wednesday 9-11:30	&TRW—DATA SYSTEMS, 12911 Simms, Avenue, Hawthorne, California
3/12 P.M.	Wednesday 2-4:30	&XEROX DATA SYSTEMS, 701 South Aviation Boulevard, Segundo, California
3/13 A.M.-P.M.	Thursday 9-3:00	&HUGHES AIRCRAFT COMPANY, Centinella & Teale, Culver City, California
3/14 A.M.	Friday 9-11:30	ITT GILFILLAN, 2821 Orion, Van Nuys, California—Van park in roped area of parking lot—Others park near van.
3/14 P.M.	Friday 2-4:30	*RCA CORPORATION, 8500 Balboa Boulevard, Van Nuys Calif. Van park in #306 parking lot—Others park near van.
3/17	Monday	DRIVE DAY
3/18 A.M.	Tuesday 9-11:30	HEWLETT PACKARD, 815—14th S.W., Loveland, Colorado—Van park at North side of Building #1A— Others in adjacent parking lot.
3/18 P.M.	Tuesday 2-4:30	*IBM CORPORATION, 6300 Diagonal Highway, Boulder, Colorado Van park in lot West of Building #021—Others park near van.
3/19 A.M.	Wednesday 9-11:30	STORAGE TECHNOLOGY, 2270 South 88th, Louisville, Colorado Van park North of entrance to Building #2—Others use parking lot.
3/19 P.M.	Wednesday 2-4:30	HONEYWELL, 4800 East Dry Creek Road, Littleton, Colorado Van park at East side of Building near employee entrance Others use visitors parking lot.
3/20 A.M.	Thursday 9-12:00	&MARTIN MARIETTA, 12250 South Highway 75, Littleton, Colorado—Van park in roped area near Engineering—Others park near van.
3/21	Friday	DRIVE DAY
3/24 A.M.	Monday 9-12:00	COLLINS RADIO, 5225 'C' Avenue N.E., Cedar Rapids, Iowa Van park at north of Building #108—Others park near van.
3/25 A.M.-P.M.	Tuesday 10:30-2:00	*IBM CORPORATION, 3605 Highway 52 North, Rochester, Minnesota—Van park on right side of circle and flag pole at entrance—Others use visitors lot.
3/26 A.M.	Wednesday 9-11:30	&HONEYWELL, AEROSPACE DIVISION, 2600 Ridgeway Road, Minneapolis, Minnesota
		INVITEE: HONEYWELL, 600 2nd St. North, Hopkins, Minn.
3/26 P.M.	Wednesday 2-4:30	*SPERRY UNIVAC, 2276 Highcrest Drive, St. Paul, Minnesota Van park at North end of Building #1—Security will direct others.
3/27 A.M.	Thursday 9-11:30	&3M CORPORATION, 2501 Hudson Road, St. Paul, Minnesota
3/27 P.M.	Thursday 2-4:30	CONTROL DATA CORPORATION, 4201 North Lexington Avenue, St. Paul, Minnesota—Van park at south side of building—Others park near van.
3/28	Friday	DRIVE DAY
3/31 A.M.	Monday 9-11:30	&WESTERN ELECTRIC COMPANY, 4513 Western Avenue, Lisle, Illinois
3/31 P.M.	Monday 2-4:30	&MOTOROLA COMMUNICATIONS, 1301 Algonquin, Schaumburg, Illinois
4/1 A.M.	Tuesday 9-11:30	&QUASAR, 9401 West Grand Avenue, Franklin Park, Illinois
4/1 P.M.	Tuesday 2-4:30	*TELETYPE CORPORATION, 5555 West Touhy, Skokie, Illinois Van enter Gate #7 (Carpenter Road), Guard will direct—Others enter Gate #6 (Carpenter Road) park in R & D visitor parking.

*Indicates NO VISITORS ALLOWED—Van and Exhibitor Personnel Only. &Indicates the Plant has not replied on the visitor question. An absence of any markings before the Plant name indicates the Plant *is* open to visitors.

EDN DESIGN AWARDS

Digital lowpass holds output until input stabilizes

Michael Stiglianese
Cincinnati Electronics Corp., Cincinnati, OH

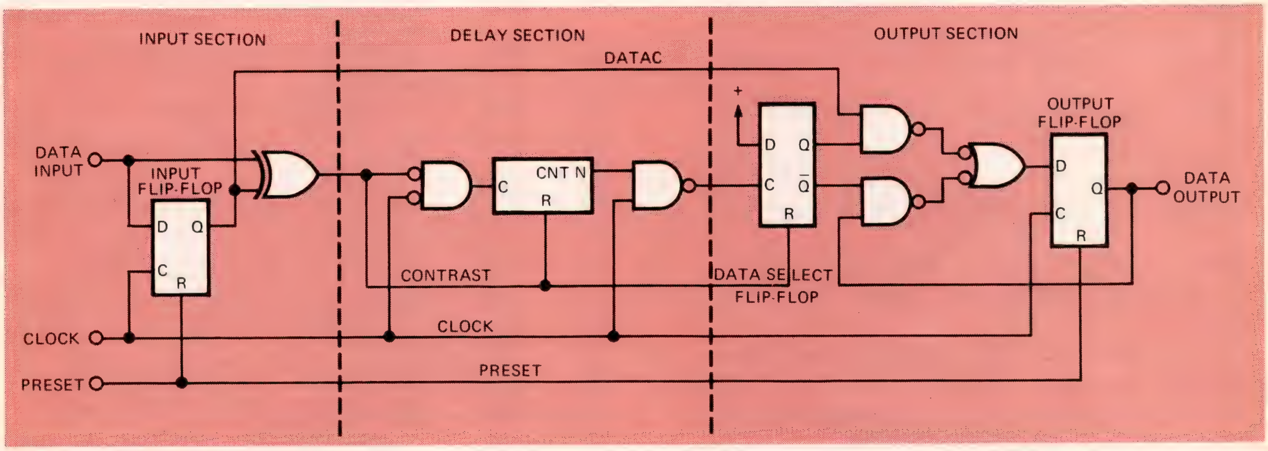


Fig. 1—Arbitrary output state changes are eliminated in this simple digital low-pass filter, making it suitable for use in high-noise environments. Filter cutoff frequency is incrementally independent of system clock frequency.

Although many simple digital low-pass filters will hunt (change output state arbitrarily) when presented with a high-frequency input, this restraint is often unacceptable in high-noise-environment systems. The simple filter shown in **Fig. 1**, however, has an unusual property (from an analog point of view). Its output state will be maintained until the input is found to be unflinchingly constant for N + 2 clock periods. Another special property, obtained through the use of a divide-by-N circuit, is that the filter's cutoff frequency is incrementally independent of system clock frequency.

Three simple sections compose the filter: input, delay and output. Incidentally, the counter and all flip-flops are positive edge-triggered.

Two signals are produced by the input section: A clocked version of the input data (DATAC) is presented to the output section, while a "CNTRST" signal resets the delay section whenever the input data differs from "DATAC."

When the input data state coincides with the state of "DATAC," the exclusive-OR forces the

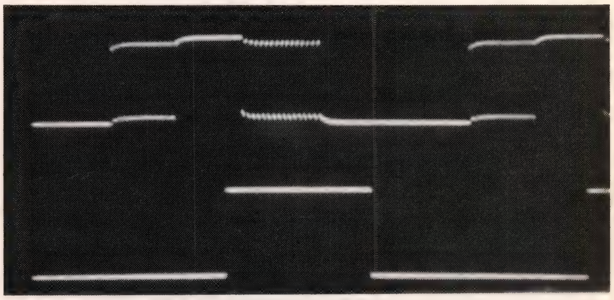


Fig. 2—Noisy edges of input data stream (**upper trace**) are cleaned up at the filter's output (**lower trace**). Time axis in **Figs. 2, 3 and 4** proceeds from right to left.

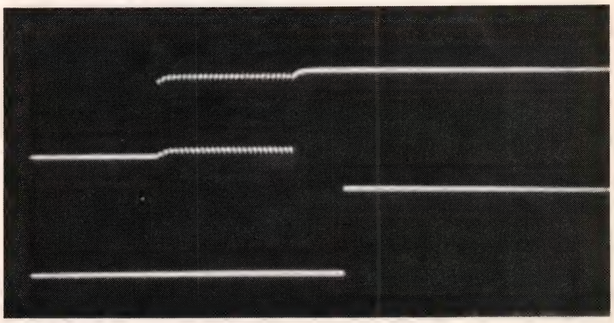


Fig. 3—After the oscillations of the ill-defined input edge (**upper trace**) have settled, a single output edge is produced (**lower trace**).

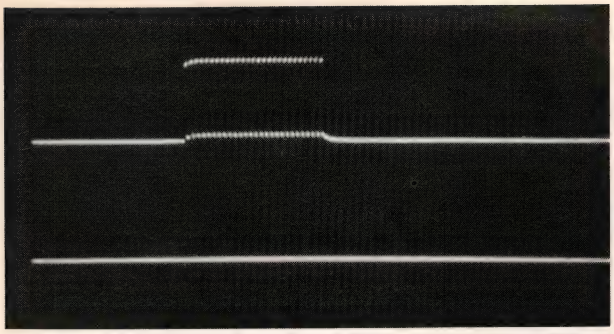


Fig. 4—Spurious noise bursts on the input data line (**upper trace**) don't affect the output of the filter (**lower trace**).

"CNTRST" signal LOW, thus enabling inverted clocks to advance the N-counter. If the input data changes state at any time during the counting, "CNTRST" will go HIGH, resetting the counter to "CNT 0," and holding the data select flip-flop reset. If the input data remains constant for a time greater than N clock periods, the fall of the clock at time N + 1 sets the data select flip-flop. This, in turn, allows the data to be strobed into the output flip-flop on the next rising clock edge. Whenever input data is not allowed to pass to the output because of transitions, the output flip-flop is gated back on itself to retain its former state.

Figs. 2, 3 and 4 show the filter in action. The upper trace in **Fig. 2** displays a very noisy-edged data stream; the lower, the clean edges of the output. (Note: Time axis of all of these photographs proceeds from right to left.) In **Fig. 3**, the output is seen to produce a single edge after the ill-defined input edge has settled. Finally, **Fig. 4** shows the output to be immune to spurious bursts on the data line. ☐

To Vote For This Circuit
Circle 160

Gated oscillator produces uniform period from start

Ralph Tenny
Texas Instruments, Dallas, TX

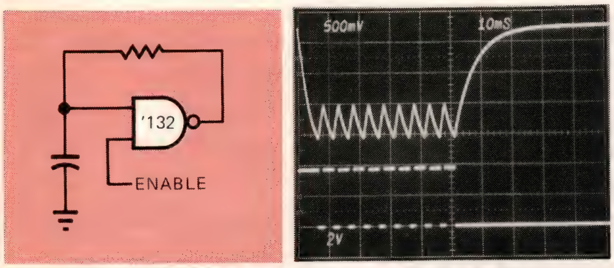


Fig. 1—Capacitor can charge to a voltage well above upper Schmitt-trigger threshold when this standard gated oscillator is in the OFF state. Thus, period of first cycle can be 2× period of successive cycles.

Most gated oscillators have a 1-cycle anomaly on start-up, as demonstrated by the TTL Schmitt-trigger (SN7413, SN74132) oscillator shown in **Fig. 1**. The associated waveforms clearly show the reason—the OFF state permits the capacitor to charge to a voltage well above the upper Schmitt threshold. This allows the period of the first cycle to be twice as long as the period of successive cycles.

However, if a potentiometer is added (**Fig. 2**), it's possible to center the feedback voltage excursions around the Schmitt thresholds. Now the starting cycle will have a period equal to those of successive cycles. ☐

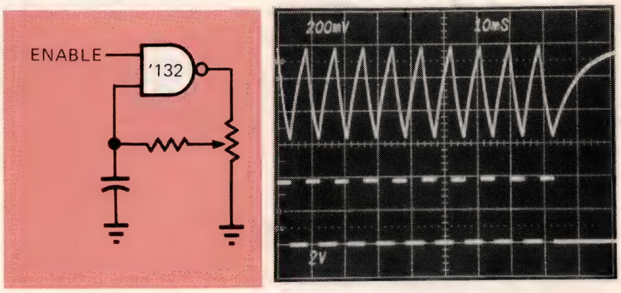


Fig. 2—Adding a potentiometer allows feedback excursions to be centered around Schmitt thresholds. Start-up anomaly disappears with proper adjustment.

To Vote For This Circuit
Circle 161

Find N^{th}-order roots on inexpensive calculators

Charles R. Brandow
Saratoga Industries, Saratoga Springs, NY

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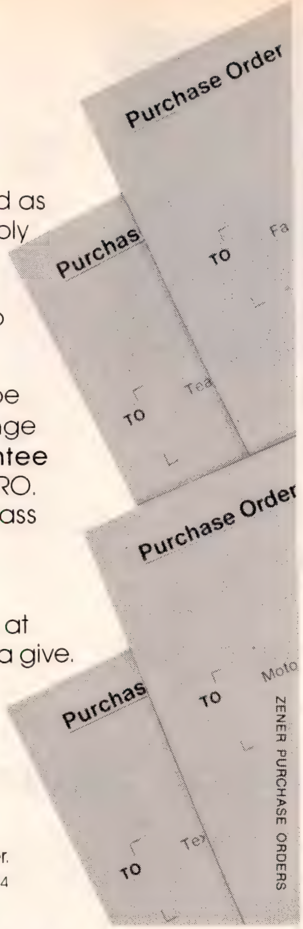

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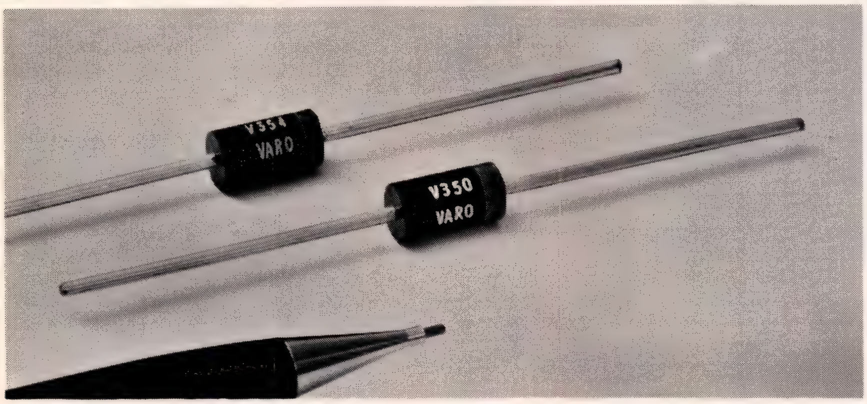

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The following method computes $\sqrt[2]{\ }$, $\sqrt[3]{\ }$, $\sqrt[4]{\ }$, $\sqrt[N^{th}]{\ }$ roots. Really an application of Newton's method, it can be used with any inexpensive 4-function calculator that has one memory.

Let—

x = Number whose root is desired
m = Number in memory
m^1 = Desired root

Procedure:

1) Guess at the root of the number. Enter this number in memory.

2) Enter x.

3) Divide x by m one less time than the desired root; i.e., twice for the $\sqrt[3]{\ }$, three times for $\sqrt[4]{\ }$, N − 1 times for $\sqrt[N]{\ }$.

4) Add m to the resultant of step 3 one less time than the desired root; i.e., twice for the $\sqrt[3]{\ }$, three times for $\sqrt[4]{\ }$, N − 1 times for the Nth root.

5) Divide the result of step 4 by the desired root, i.e., three for $\sqrt[3]{\ }$, four for $\sqrt[4]{\ }$, N for the Nth root.

6) Enter the result in the memory—this becomes m^1.

7) Repeat steps 2 thru 6 to arrive at the root to the accuracy desired.

Example: Find the $\sqrt[3]{269}$

Step 1) Guess at the number and enter in memory (m)
2) enter 269
3) ÷ m
4) ÷ m
5) + m
6) + m
7) ÷ 3
8) Update memory with this new number
9) Repeat steps 2 thru 8 as often as necessary

Result:

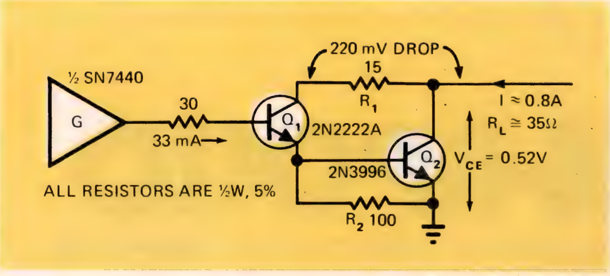
$\sqrt[3]{269} = 6.4553146$; $(6.4553146)^3 = 268.99996$

Note: Accuracy of guess in step #1 determines the number of times steps 2—8 have to be repeated. □

To Vote For This Circuit
Circle 162

Fast power switch self-corrects for degradation

Carlo Venditti
Charles Stark Draper Labs., Inc., Cambridge, MA



Turn-ON and turn-OFF times for this switching cell are consistent and faster than conventional darlingtons or single saturated-transistor circuits.

This circuit uses standard T²L-SSI to achieve fast turn ON and OFF times while switching amperes of current. The switching cell (SC) is made up of two transistors. Driver transistor Q_1 is a low-power device with fast switching times. Q_2, the power device, handles the power dissipation and current being switched. The SC can be used in circuits requiring fast solid-state switches and in circuit applications where the switching times must be known and repeatable from circuit to circuit.

When gate G's output goes to the ONE state, it turns Q_1 ON with a fixed base drive. During the transition from OFF to before saturation, the base drive to Q_1 is amplified by the h_{FE} of Q_1 and forces Q_2 to turn ON hard. The measured t_{ON} for the SC as shown is approx. 50 nsec. Sufficient base drive is provided to saturate Q_1. This forces the excess base drive to develop a voltage drop across the 15Ω resistors connecting the two collectors.

The value of $V_{CE,Q2}$ for this circuit was measured at 0.52V with collector current of 800 mA. The effective $V_{CE,Q2}$ is not too sensitive to its h_{FE}, since Q_2 is operated in a quasi-saturated condition. For example, using a lower h_{FE} device requires more base current and causes V_{CE} to increase, thereby increasing its h_{FE}. This results in a decrease in base drive to maintain the collector current. An opposite mechanism takes place if h_{FE} is higher.

When the gate output goes to the ZERO state, Q_1 turns OFF, allowing Q_2 to turn OFF from the quasi-saturated condition. The total Q_2 off-time is determined primarily by the t_{OFF} of Q_1, some switching properties of Q_2 (e.g., C_{CB}), and effective load resistance.

Using the SC described, the following operating conditions can be realized:

- Better turn-OFF times and less power dissipation are attained than with the conventional Darlington.

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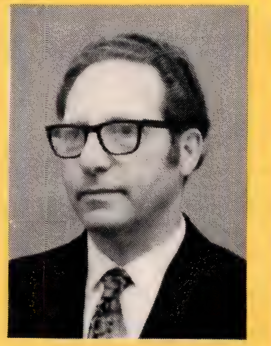
- During SC OFF state, the base-emitter of Q_1 and base-emitter of Q_2 are clamped almost to ground. This allows use of lower voltage transistors since the BV_{CEO} approaches BV_{CES}, which is higher.
- Circuit is not sensitive to the h_{FE} of Q_2, making transistor matching unnecessary.
- Circuit maintains a fast and predictable ON-OFF time, which is essential in some circuit applications; e.g., symmetrical push-pull inverters.
- SC gives a constant power dissipation.
- It realizes fast turn ON-OFF times with its inherent simplicity, using a constant-current base drive.
- SC limits the collector current of Q_1 to a safe value during ON transition.
- Circuit will maintain its properties even if h_{FE} of Q_2 degrades due to time or environment. □

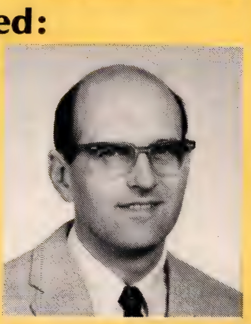
To Vote For This Circuit
Circle 163

Readers have voted:



Richard W. Hofheimer winner of the March 5, 1974 U.S. Savings Bond Award. His winning circuit is "Get 50% Duty Cycle From IC Timer With Two R's & One C." Mr. Hofheimer is with Non-Linear Systems, Del Mar, CA.

Readers have voted:



William Lee Mahood winner of the April 5, 1974 U.S. Savings Bond Award. His winning circuit is "Tester For Balanced Audio Lines." Mr. Mahood is with E-Systems, Inc., Falls Church, VA.

Readers have voted:

Peter Alfke winner of the July 20, 1974 U. S. Savings Bond Award. His winning circuit is "Low cost 7-segment-to-BCD converter is simple, fast." Mr. Alfke is with Fairchild Semiconductor, Mt. View, CA.

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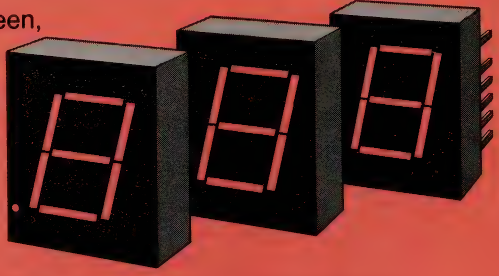


• Large .6" (16mm) high, seven segment characters for wide angle and distance viewing • Choice of red, yellow or green, common anode, left decimal displays • Unique, reflectorized design for high contrast ratio • Extremely low, IC-compatible power requirements: Vf = 2.0V; If = 20mA • Dual-in-line, 18-pin, .83" C/C packaging for easy installation • Low cost per digit

Circle No. 8

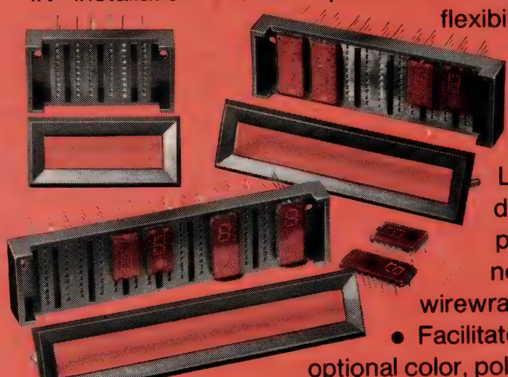
IEE
the Olympus of displays

Industrial Electronic Engineers, Inc.
7740 Lemona Ave., Van Nuys, Calif. 91405
Phone: (213) 787-0311
TWX 910-495-1707

European Office: 6707 Schifferstadt, Eichendorff-Allee 19, Germany.

IEE•ATLAS™
UNIVERSAL DISPLAY MOUNTING HARDWARE

• Provides automatically self-aligning, unitized, "SLIP-IN" installation • Offers optional two through eight digit flexibility • Accommodates all standard 14/16 pin, DIP-packaged LED and planar displays • Simplifies interconnection through wirewrap terminations • Facilitates wide-angle, optional color, polarized viewing • Forever puts an end to "do-it-yourself" installation problems

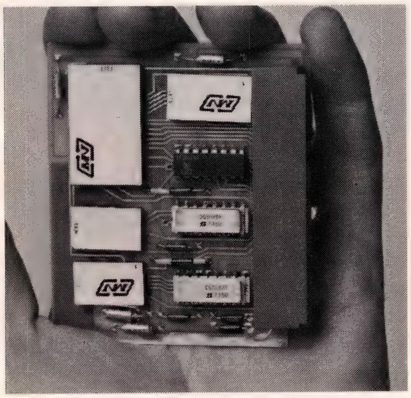


Circle No. 9

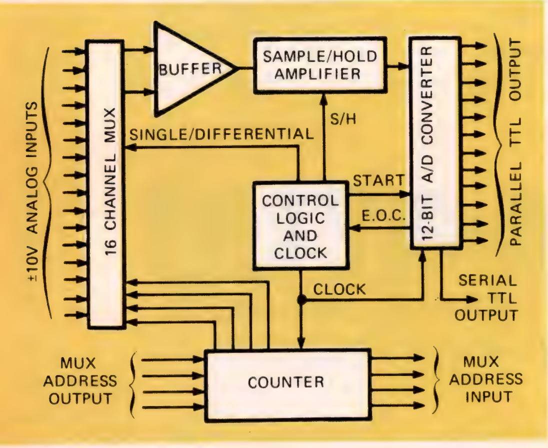
To find your local IEE Representative
Call Toll-Free DIAL-A-SOURCE (800) 645-9200

Diminutive data acquisition system needs no adjustments

PROGRESS IN COMPONENTS/CIRCUITS



Handling is necessary only when the Micro Networks' Model MNA-7000 is installed. Thereafter, it's hands off, because operation is adjustment free—no trimming required.



All necessary circuitry for complete system operation is provided, including a 1-MHz internal clock. MNA-7000 series' internal reference is brought out through 77-pin AMP-MIL connector for error compensation.

If you define an electronic component as a self-contained, fully specified, adjustment-free device, then components have reached a new level of sophistication. Micro Networks' MNA-7000 Series, two high speed 16-channel, 12-bit data acquisition systems, conform to all aspects of this definition.

Constructed with hermetically-sealed microelectronic circuits, Models 7000 and 7000H are totally self-contained (measuring only 2.75×3.15×0.45 in.) and fully specified (including ±1 LSB linearity over −55 to +125°C for the "H" version). Moreover, they require no external adjustments. (In fact, none are provided.)

Meeting industry's needs

The MNA-7000 series' packaging concept satisfies two significant industry needs.

At a time when microprocessors and semiconductor memories are emerging as viable and revolutionary technologies, a real need exists for miniature data acquisition peripherals to keep total system size down to a reasonable scale.

In addition, at a time when the cost of labor is high and continuously rising, adjustment-free operation is extremely desirable, if not an economic necessity, in many electronic systems. Not only does the absence of adjustments lower operating costs, it also permits unattended operation in remote locations, thus opening up new areas of application.

Throughput to 40 kHz

Both the 0-70°C MNA-7000 and −55 to +125°C MNA-7000H are versatile performers. They can operate in the 16-channel single ended, 8-channel true differential, or 16-channel pseudo-differential mode. Input impedance of 100 MΩ min. and crosstalk of −80 dB min. are guaranteed for all operating modes.

Conversion time of a single channel to a digital output is guaranteed to be < 28 μsec (35,000 conversion/sec). However, in the repetitive mode, MUX overlap reduces conversion time to under 25 μsec (40-kHz throughput rate).

The MNA-7000 is $695 (1-99), while the premium MNA-7000H is $1395. Delivery is two to four weeks.

Micro Networks Corp., 324 Clark St., Worcester, MA 01606. Phone (617)852-5400.

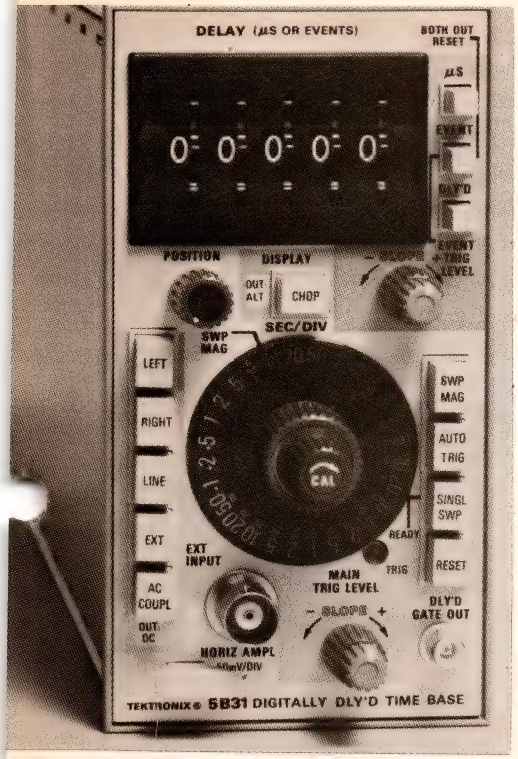
Circle No. 140

Digital delay gives time base new accuracy, cuts jitter way down

PROGRESS IN INSTRUMENTATION

Conventional delaying time bases always have been limited by the analog design. They lack the degree of accuracy necessary for many applications, can't always locate and display unknown events with precision, and sometimes cause jitter in the display. Too, their complicated dial settings and multipliers can be confusing.

Now the Tektronix 5B31 digitally delayed time base, (a plug-in for the 5400-series scopes) provides exceptional



Precise setting and stability give this digital time base an edge over conventional analog types.

accuracy, along with freedom from most jitter. Its digital pushbuttons and thumbwheels eliminate the ambiguity of dials and multipliers, making it easy to set the number of delaying events or time periods. The delay system—a crystal-controlled clock, a digital counter, and a unique circuit that removes 1-count ambiguity in the counter—replaces the usual delaying time base.

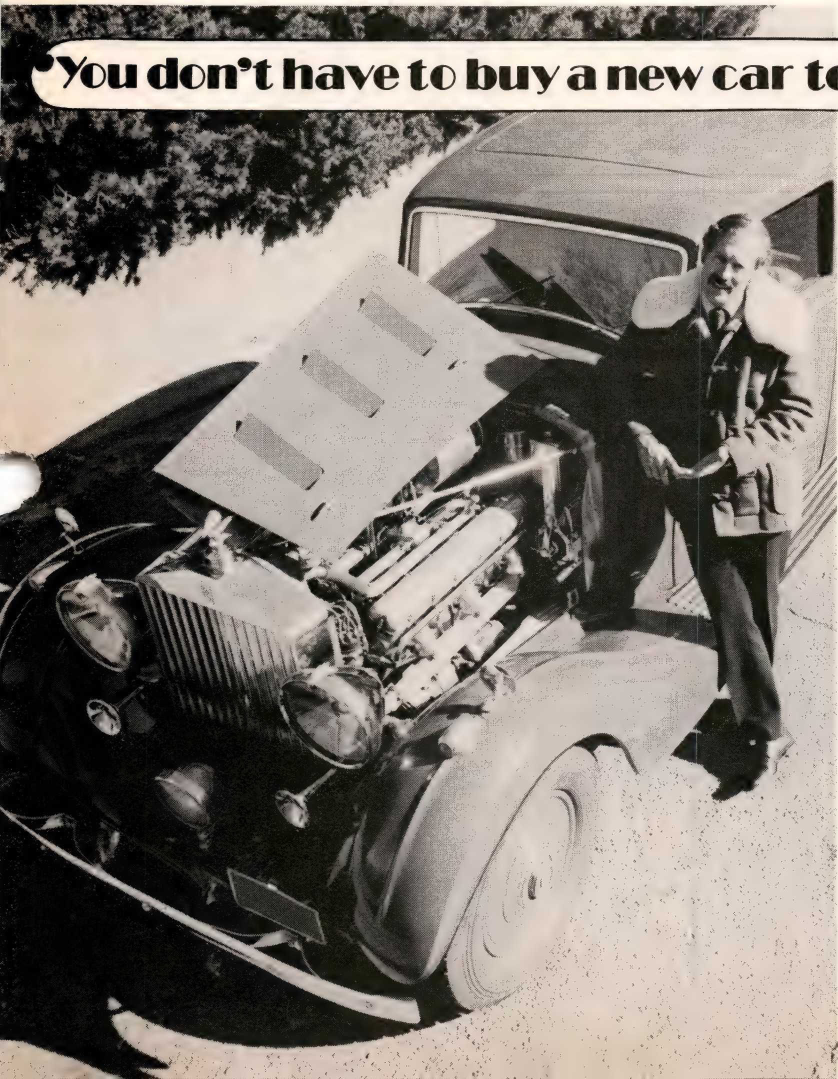
What it can do. The delay-by-events mode, made possible by the digital counter, lets you use the 5-digit thumbwheel switch to display the number of events that follows the main triggering event before the sweep starts. This mode provides a powerful diagnostic tool in the analysis of high-jitter digital data streams like those from disc memories or tape recorders.

The delay time can be incremented in 1-µsec steps from 0 to 99,999 µsec (almost 0.1 sec), and read directly from the thumbwheel switch. Delay jitter is <10 nsec plus 1 part in 10^7, so that the fastest unmagnified sweep (200 nsec/div.) can be used at the longest delay (0.1 sec).

Where the conventional delaying time base requires two sweeps, the 5B31 requires only one. Selection of either mode—µS or EVENTS—causes an intensified zone to appear on the CRT display, provided the sweep lasts longer than the selected delay. The intensified zone starts at the end of the delay, and continues to the end of the sweep. When the DLY'd push button is pressed, the sweep starts at the end of the selected delay.

Tektronix, Inc., Box 500, Beaverton, OR 95007. Phone(503)644-0161.

Circle No. 141



"You don't have to buy a new car to get an electronic ignition."

Let's face it. After 37 years, even a Phantom III can use a lift. That's why I put a Delta Mark Ten B Capacitive Discharge Ignition on my Phantom . . . to give her a spark I'd pit against any '75 model car. I went to Delta because they aren't Johnny-come-latelys. Delta's been making electronic ignition systems for over a decade.

Whatever kind of car you drive, you can give it the same great Delta performance I gave mine.

- Mark Ten B Capacitive Discharge Ignition Systems are manufactured by Delta Products, Inc., a company with a conscience, and with a proven record of reliability both in product and in customer relations.
- The Mark Ten B really does save money by eliminating the need for 2 out of 3 tune-ups. Figure it out for yourself. The first tune-up or two saved pays for the unit, the rest is money in your pocket. No bunk!
- Because the Mark Ten B keeps your car in better tune, you actually can save on expensive gasoline.
- With a Mark Ten B, spark plugs stay clean and last longer . . . fouling is virtually eliminated.

For more information, Circle No. 33

I want to know more about Mark Ten B CDI's. Send me complete no-nonsense information on how they can improve the performance of my car.

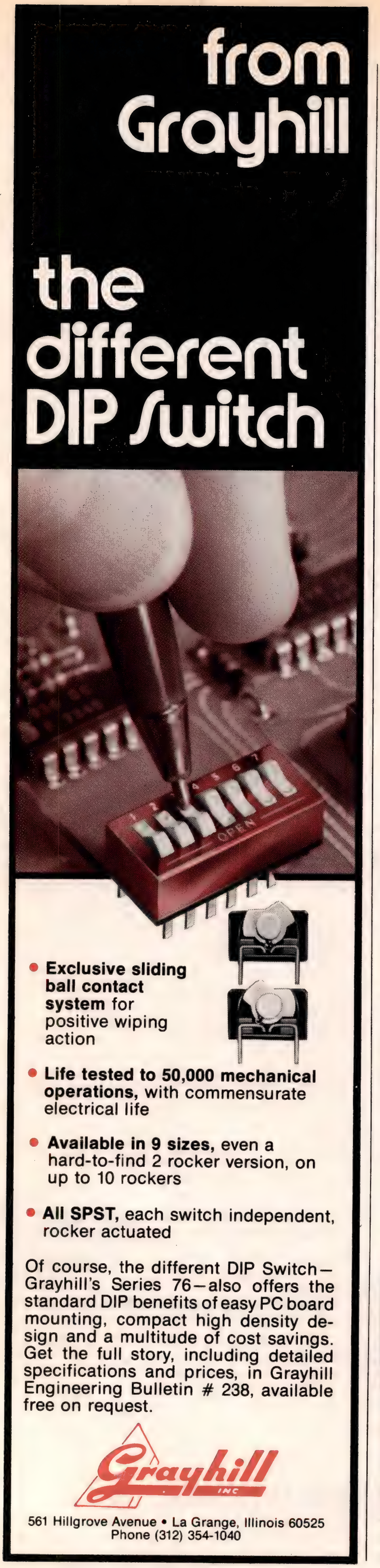
Name__________

Address__________

City__________State__________Zip__________

DELTA PRODUCTS, INC.
P.O. Box 1147, Dept. EDN, Grand Junction, Colo. 81501
303-242-9000

Mark Ten B, assembled . . . . . . $64.95 ppd
Mark Ten B, kit . . . . $49.95 ppd
Standard Mark Ten, assembled . . . . . . $49.95 ppd
Deltakit® . . . . $34.95 ppd



from Grayhill

the different DIP Switch

- **Exclusive sliding ball contact system** for positive wiping action
- **Life tested to 50,000 mechanical operations,** with commensurate electrical life
- **Available in 9 sizes,** even a hard-to-find 2 rocker version, on up to 10 rockers
- **All SPST,** each switch independent, rocker actuated

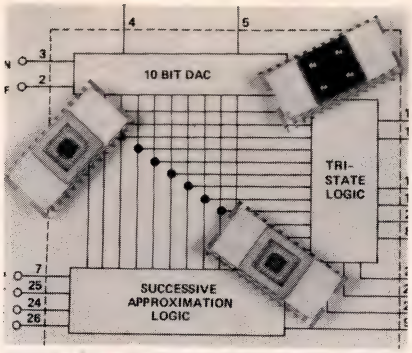
Of course, the different DIP Switch—Grayhill's Series 76—also offers the standard DIP benefits of easy PC board mounting, compact high density design and a multitude of cost savings. Get the full story, including detailed specifications and prices, in Grayhill Engineering Bulletin # 238, available free on request.

Grayhill INC

561 Hillgrove Avenue • La Grange, Illinois 60525
Phone (312) 354-1040

For more information, Circle No. 34

SEMICONDUCTORS



FIRST MONOLITHIC 10-BIT CMOS ADC AIMS AT μP INTERFACES. Featuring thin-film on CMOS construction and microprocessor compatibility, the successive-approximation AD7570 achieves a 20-μsec conversion time with only 20 mW quiescent dissipation. Its inherently ratiometric operation requires adding an external comparator and RC network, a ±10V reference and a 15V supply. AD7570 guarantees no missing codes (0 to 75°C) and specifies a 10 ppm of F.S./°C gain TC. $69 (1-49). Analog Devices, Inc., Box 280, Norwood, MA 02062. Phone(617)329-4700.

Circle No. 171

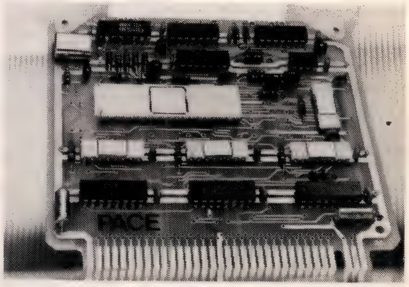
CMOS MEMORY IS CONTENT ADDRESSABLE. A CAM (Content Addressable Memory) is a new class of component for computer architecture. Capable of performing an exact match search, the device can tell whether an input word is or isn't stored in memory. The unit has a conventional read/write capability and can be used as a 64-bit RAM. Inputs are CMOS compatible, and outputs are tri-state MOS or TTL compatible. Housed in a 48-pin ceramic DIP, the unit costs $21(1000). Solid State Scientific, Inc., Commerce Dr., Montgomerville, PA 18936. Phone(215)855-8400. **Circle No. 172**

LOGICAL OR GATES ARE QUICK AND STINGY. Operating in 14 nsec, but using one-fifth the power of ordinary TTL devices, the gates are available in both MIL (S54LS32F) and commercial (N74LS32A) grades. Both versions of the quadruple 2-input OR gates are manufactured in two types of 14-pin DIP's, plastic and ceramic. Signetics, 811 E. Arques Ave., Sunnyvale, CA 94086. Phone(408)739-7700. **INQUIRE DIRECT.**

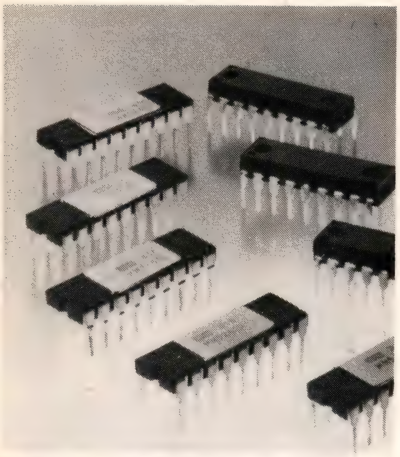
LSI 1k UNIT LEADS OFF FAMILY OF SOLID-STATE MEMORIES. This high-speed device is the first in a series of NMOS solid-state memories. Pin compatible with the AMS 7001I, the unit features 60-nsec max. access time, 180-nsec max. cycle time, TTL-compatible inputs and 640-μW/bit max. operating power dissipation. MW7001ID, $10.50(1000). RCA/Solid State Div., Rte. 202, Somerville, NJ 08876. Phone(201)722-3200. **Circle No. 173**

SILICON POWER TRANSISTORS HANDLE 30A. Packaged in a JEDEC TO-3 case, these homogeneous-base npn units are constructed on a single-diffused chip. Typ. features of the 2N6258 are $V_{CEO}>80V$, V_{CBO} of 100V and a min. gain of 20 @ 15A. The 2N6259 offers $V_{CEO}>150V$, V_{CBO} of 170V and a min. gain of 15@ 8A. $3.75(100-999) and $4.50(100-999), respectively. Solitron Devices Inc., 1177 Blue Heron Blvd., Riviera Beach, FL 33404. Phone(305)848-4311.

Circle No. 174



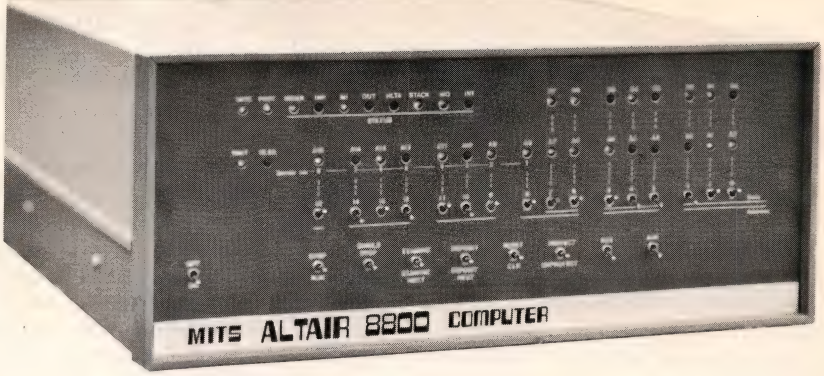
P-CHANNEL MICROPROCESSOR (μP) HAS 16-BIT FORMAT. Two power supplies, +5V and −12V, and 10-μsec instruction execution time are featured in PACE, a single-chip μP. Its instruction set includes 45 types or 337 individual instructions. The set is divided into 8 classes that include branch, skip and transfers. An internal interrupt system with an on-chip jump-condition multiplexer is available. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5007. **Circle No. 175**



4k RAM USES N-CHANNEL MOS AND TRI-SHARE CONCEPT. With only 18 leads, the MM5270 allows users to achieve a pc-card memory density nearly twice as great as that possible with 22-lead 4k RAM's. A unique design concept, Tri-Share, allows a single lead to serve 3 functions: Read/Write, logical Chip Select and V_{CC}. TTL-compatible inputs and on-chip registers for address and Chip Select are included. Available in mid-1975. National Semiconductor Corp., 2900 Semiconductor Dr., Santa Clara, CA 95051. Phone(408)732-5000.
Circle No. 176

IC ANALOG MULTIPLEXERS FEATURE LOW POWER. Two devices, constructed with failure-protected CMOS, are both DTL/TTL and CMOS compatible. The MPC16S is a 16-channel single-ended unit, while the MPC8D is a dual 8-channel device for differential inputs. Both units are monolithic and consume 15 mW @ 100 kHz. An enable line is available to allow the user to individually enable a channel group. MPC16S $42(1), $29(100). MPC8D $45(1), $29.80(100). Burr-Brown, International Airport Industrial Park, Tucson, AZ 85706. Phone(602)294-1431. **Circle No. 177**

SHIFT REGISTERS OFFER 50% BETTER SPEED/POWER PRODUCT. Using a p-channel silicon gate process, this register family features low clock capacitance (85 pf) and 200-mW power dissipation. Ion implantation yields a chip the same size, speed and cost as conventional devices. The S41402A, a 16-pin ceramic device, is $7.10 (100-999). The 1403A and 1404A, packaged in an 8-pin metal can or 8-pin DIP, are $5.50(100-999). Synertek, 3050 Coronado Dr., Santa Clara, CA 95051. Phone(408)241-4300. **Circle No. 178**



A COMPUTER CONCEPT BECOMES AN EXCITING REALITY.

Not too long ago, the thought of an honest, full-blown computer that sells for less than $500 would have been considered a mere pipe dream.

Everyone knows that computers are monstrous, box-shaped machines that sell for 10's and 100's of thousands of dollars.

Pipe dream or not, *MITS,* the quality engineering oriented company that pioneered the calculator market, has made the *Altair 8800* a reality. It is the realization of that day when computers are accessible to almost anyone who wants one.

The heart (and the secret) of the *MITS Altair 8800* is the *Intel 8080* processor chip. Thanks to rapid advances in integrated circuit technology, this one IC chip can now do what once took thousands of electronic components (including 100's of IC's) and miles of wire.

Make no mistake about it. The *MITS Altair 8800* is a lot of brain power. Its parallel, 8-bit processor uses a 16-bit address. It has 78 basic machine instructions with variances up to 200 instructions. That's more than enough to program all the street lights in a major city.

And the *MITS Altair 8800 Computer* is fast. Very fast. Its basic instruction cycle time is 2 microseconds.

Combine this speed and power with the *Altair's* flexibility (it can directly address 256 input and 256 output devices) and you have a computer that's competitive with most mini's on the market today. And sells for a fraction of their cost.

The Altair 8800 has been designed to fulfill a wide variety of computer needs. It is ideal for the hobbyist who wants to get involved with computers. Yet, it has the power and versatility for the most advanced data processing requirements.

Its basic memory of 256 words of static RAM memory can be expanded to 65,000 words of directly addressable memory. Static OR dynamic memory. OR PROM or ROM memory. OR a floppy disc system. All supplied by *MITS.*

MITS wants to service your individual computer needs.

You can buy an assembled *Altair 8800.* Or you can start by building the computer yourself. The *MITS Altair 8800* is the ultimate kit. Its assembly isn't much more difficult than assembling a desktop calculator.

OR you can start with an *Altair 8800* computer data processing system. *Altair Systems* come in 4 basic configurations.

For those users who are not familiar with computers, *MITS* offers free consultation service. Just describe your requirements to our engineering staff and we will specify the additional cards and the system configuration you need to do the job.

The MITS Altair 8800 is backed by complete peripheral and software development programs. There is even a high level language available.

Order your Altair 8800 Computer today. As a special introductory offer, *MITS* is offering the *Altair 8800* at a discount of $100. This offer is good on all orders postmarked prior to March 1, 1975.

PRICES:

Altair 8800 Computer (assembled with complete operation instructions) **$750.00**
Altair 8800 Computer (kit form) **$495.00**
Subtract $100.00 from above prices on all orders postmarked prior to March 1, 1975.

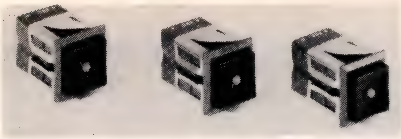
MITS INC.®
"Creative Electronics"

Warranty: 90 days on parts and labor for assembled units. 90 days on parts for kits.
Prices, specifications and delivery subject to change without notice.

☐ Enclosed is a Check for $ ________
or ☐ Bank Americard # ________
or ☐ Master Charge # ________
Credit Card Expiration Date ☐ Kit
Include $8.00 for Postage and Handling ☐ Assembled
☐ ALTAIR 8800
☐ Please send complete Altair System Catalogue.
NAME ________
ADDRESS ________
City ________
STATE & ZIP ________
MITS / 6328 Linn, N.E., Albuquerque, New Mexico 87108 505/265-7553

For more information, Circle No. 35

COMPONENTS/MATERIALS



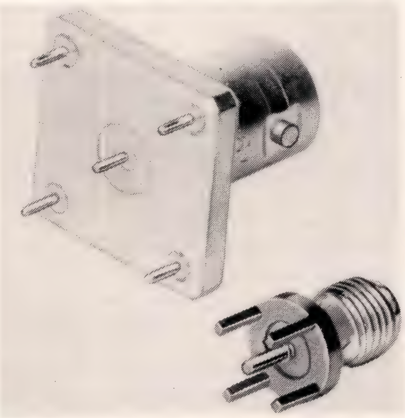
PUSHBUTTON SWITCHES OFFER LONG-LIFE LED ILLUMINATION. Series DUS switches use a LED in the center of their square concave pushbuttons. The LED operates on 6V dc and offers full 180° viewing. The switches feature 1-A (spst, N.O.) momentary action, snap-in mounting and contact terminals of silver-plated brass, rated at 250 mA, 30W for non-inductive ac load. $5. Switchcraft, Inc., 5555 No. Elston Ave., Chicago, IL 60630. Phone(312)792-2700.
Circle No. 179

GAS-TUBE SURGE ARRESTER ACTS FAST. Model TII-317 is a 3-electrode unit potted in epoxy. It weighs 1/2 oz. and measures only 2×7/16 in. Three models, TII-317, A, B and C, fire at dc voltages of 150-300, 300-500, and 500-900, respectively. In operation, if either leg sees a surge of voltage high enough to fire it, the entire common 3-electrode chamber becomes ionized and grounds the surge. Breakdown time is <0.1 μsec for an impulse of 10 kV/μsec. $5.35. Telecommunications Industries, Inc., 1375 Akron St., Copiague, NY 11726. Phone (516)842-5000. **Circle No. 180**

MINIATURE TEMP. RECORDERS COME IN 3- OR 4-INCREMENT MODELS. Temp-Plate^R self-adhesive recorders are accurate to ±1% over a range of 37 to 260°C in increments of 5°C. When exposed to the rated critical temperature, the indicators turn in sequence from silver to black for a direct readout that is both permanent and irreversible. The rated temperature is printed below each indicator window. A free sample and catalog are available. William Wahl Corp., 12908 Panama St., Los Angeles, CA 90066. Phone(213)391-7234.
Circle No. 181

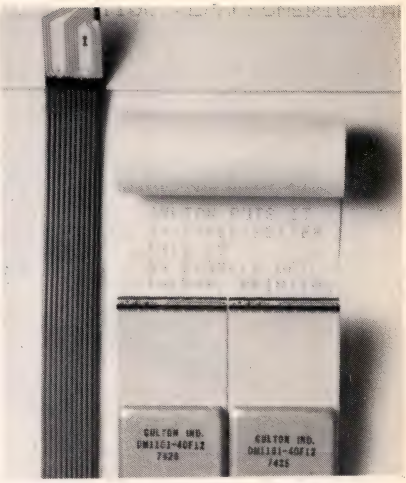
MOUNTING PADS CONVERT TO-5 TYPE IC'S TO DIP PATTERN. Funnel-shaped, self-aligning lead entries in these spreader pads accept circular patterned devices and form a DIP pattern at exit. Posts on the top and feet on the bottom provide cleaning and probing ease. Soldered components may be removed from the top of the board. Units are color coded: 8-lead (blue), 10-lead (red) and 12-lead (white). 3.625¢ each in 10k lots. Bivar, Inc., 1617 E. Edinger Ave., Santa Ana, CA 92705. Phone(714)547-5832. **Circle No. 182**

MULTIPLE ROTARY PC-BOARD SWITCH ASSEMBLIES SAVE SPACE. These switches feature metal pc edge-mount terminals for easy plugging into a mother board. Models can be custom designed for limited-space applications. Choices include any circuitry pattern desired and as many wafer decks as necessary, with up to 20 positions/deck. Resistors, diodes and similar components can be added to individual switch boards. Standard Grigsby, Inc., 920 Rathbone Ave., Aurora, IL 60507. Phone(312)897-8417. **Circle No. 183**



PC-BOARD COAXIAL JACKS SIMPLIFY ASSEMBLY. Available in both BNC and SMA types, the jacks can be dropped into the board, then soldered in a single operation. The BNC-series jacks are designated KC-79-07 for 1/16-in. thick boards, and KC-79-153 for 1/8-in. thick boards. The SMA Series includes the straight 877-20 and the right-angle 877-21. Both can be used with 1/16 and 1/8-in. thick boards. Kings Electronics Co., 40 Marbledale Rd., Tuckahoe, NY 10707. Phone(914)793-5000.
Circle No. 184

BOUNCE-FREE KEYBOARD SWITCH STANDS 40 MILLION CYCLES. The M-5 mercury switches have sealed contacts and are solder-mounted to the pc board for easy keyboard construction. Switches are not attitude dependent. Electrical configurations include both single- and double-pole versions, with N.O. or N.C. contacts. Rating is 200 mA at 24V dc, with rise time of <10 msec. Mechanical Enterprises Inc., 8000 Forbes Pl., Springfield, VA 22151. Phone(703)321-8282. **Circle No. 185**



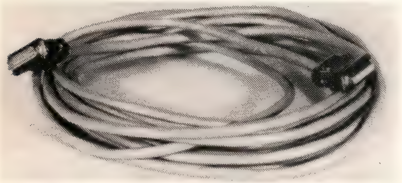
ALPHANUMERIC DOT-MATRIX THERMAL PRINTHEADS BOW IN. A versatile line for data logging applications, they include the side-printing DL 1100 10-dot character printer capable of 18 char./sec and the DM 1101 10-column expandable page printer. The DM 1101 is designed for strip and page printing. It contains a single row of 10 groups of 5 heater dots for printing up to 10 columns of 5×5 or 5×7 matrix characters. Gulton Industries Inc., 212 Durham Ave., Metuchen, NJ 08840. Phone(201)548-2800.
Circle No. 186

NOW THICK-FILM RESISTOR NETWORKS IN 14- TO 18-PIN DIP'S. Type LDP, a sandwich-style unit, has an epoxy coating between its ceramic sandwich construction. This provides excellent moisture protection over the operating temperature range of −55 to +150°C. The resistance range available spans from 10Ω to 1 MΩ with TC of ±250 ppm/°C. Tolerances available include 1, 2, 5, 10 and 20%. Price for a typical LDP (14 pins, 13 resistors, 10% tolerance): 68¢ (1000). Dale Electronics, Inc., Box 74, Norfolk, NB 68701. Phone(402)371-0080.
Circle No. 187

UL-APPROVED PLUGS AND RECEPTACLES USE CRIMP CONTACTS. Econ-A-Mate connectors feature 0.093-in. dia. crimp removable contacts for rapid assembly and applied cost savings. They are available in 1-, 3-, 9-, 12- and 15-contact layouts. Flame-retardant polypropylene is the dielectric material used. A 15-contact plug with locking slots, (Part No. 348-0093-000) costs 6.2¢ (5000), plus contacts. Part #348-0093-000 matching receptacle, with mounting ears, also is 6.2¢ (5000). Malco, 5150 W. Roosevelt Rd., Chicago, IL 60650. Phone(312)287-6700. **Circle No. 188**

FEATHERED-EDGE BLADE DESIGN LOWERS SOUND IN COOLING FAN. This design, used in the Feather^R tubeaxial fan for cooling electronic packages, acts to break up and distribute the vortices shed from the trailing edge of the blade. It practically eliminates a 2000-Hz pure tone at free delivery, keeping noise down. The 7-in. dia. high-volume units have a multi-slot induction motor with stainless steel ball bearings and shaft. Life expectancy is about 50,000 hrs. Rotron, Inc., Woodstock, NY 12498. Phone(914)679-2401. **Circle No. 189**

VERY LOW-CAPACITANCE TRANSFORMER IMPROVES ISOLATION 5X. The Nanotran IT-3458 is a low bulk-capacitance isolation transformer measuring 2-1/4×2-3/4×1-3/4-in. high. Primary rating is 115V, 45 to 65 Hz, while a tapped secondary delivers either 35.5V at 50 mA or 18V at 100 mA. Primary to secondary rating is 20 pF nominal, $10^{11}\Omega$ min. Stevens-Arnold, Inc., 7 Elkins St., South Boston, MA 02127. Phone(617)-268-1170. **Circle No. 190**



EIA DATA CABLES MEET SPECIFICATION RS232C REQUIREMENTS. These are 25-conductor cables intended for computer peripheral and data communications use. Special cable configurations are available, and cable lengths and connector polarity can be specified for quick turnaround fabrication. Price is $25 for the pair of end connectors and 70¢/ft for the cable length. International Data Sciences, 100 Nashua St., Providence, RI 02904. Phone(401)274-5100. **Circle No. 191**

surface acoustic wave devices

from the oldest and most experienced acoustic device company

Andersen brings to the Surface Acoustic Wave marketplace twenty years of design and manufacturing experience in acoustic devices and systems.

As a result, the Andersen product line of Surface Acoustic Wave devices exhibits state-of-the-art characteristics, carries a wide and flexible range of operating parameters, and is designed and fabricated with advanced computer-aided production techniques.

Surface Acoustic Wave devices offered by Andersen include **linear phase bandpass filters, phase coded delay lines, wide band dispersive delays, tapped delay lines,** and **non-dispersive delay lines.**

Because Surface Acoustic Wave devices mean low-cost signal processing, they are particularly suited to military and commercial applications in radar systems, communications systems, telemetry systems and frequency analysis systems.

Andersen also manufactures bulk wave non-dispersive delay and Imcon dispersive delay devices providing time-bandwidth products of up to 10,000:1.

Andersen's experience and capabilities make it the best company to determine the optimal acoustic technology for your application.

Call or write our Applications Engineering Department.

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203-242-0761
TWX 710-425-2390

For more information, Circle No. 36

DATA COUPLER CONVERTS PARALLEL DATA TO SERIAL. Model DC-6 accepts data from such devices as digital instruments, dataloggers, medical instrumentation, digitizers and A/D converters and converts it into form suitable for teletype circuits or for input into EIA RS-232C interfaces. The type of input selection is by plug-in cards. Up to 32 parallel bits or 8 BCD characters of input data at TTL-logic levels can be accommodated as standard. Science Accessories Corp., Kings Hwy. W., Southport, CT 06490. Phone(203)255-1526. **Circle No. 192**

DATAMATH TI-2500 ADDS % AND AUTOMATIC CONSTANT. Featuring an 8-digit LED display, it weighs <9 oz. and fits neatly in a pocket, briefcase or purse. The automatic constant allows multiplication or division of a series of numbers by 1 number, and addition or subtraction of a constant number to or from a series of numbers. Operation is either from 2 "AA"-size alkaline or nickel-cadmium batteries—or via an ac adapter/charger. $49.95. Texas Instruments Inc., Box 5012, MS 84, Dallas, TX 75222. Phone(214)238-3741. **Circle No. 193**

DIGITAL COMB NOTCH FILTER KILLS LINE HARMONICS. The filter provides almost 200 distinct, equally spaced notches. It accepts 60-Hz input, locking onto the power-line frequency and tracking it when any drift occurs (lock range is 40 to 80 Hz). Input level is 0.1 to 3V rms and output is 3V rms. A miniature 400-Hz model, the LINX-400, fits aircraft needs. From $1500 to $3000. Xetron Corp., 11079 Reading Rd., Cincinnati, OH 45241. Phone(513)563-4880. **Circle No. 194**

ROUTING MATRIX SWITCHES 24 INPUTS TO ANY 16 OUTPUTS. With the Model 2416, any input may be switched to any one output or any combination of outputs. Front-panel switches or remote inputs from an external computer provide system control. Power handling capacity is 10W dc resistive, operate time is <1 msec and frequency response is −3 dB at 5 MHz. Acroamatics, 36 Mason St., Santa Barbara, CA 93101. Phone(805) 963-9116. **Circle No. 195**

EASY-TO-USE FREQUENCY COUNTER HAS SWITCHABLE AUTORANGING. Covering 20 Hz to 5 MHz with 25 mV sensitivity, Model 6202A allows both manual and auto operating modes. In AUTO, a pushbutton will program the counter to fill the display register while automatically selecting max. frequency resolution. The 6202A also has manually adjustable input controls for setting trigger levels. Options include a battery pack, a higher stability TCXO, a 7-digit readout and BCD output. $435. Systron-Donner Corp., 10 Systron Dr., Concord, CA 94518. Phone(415)676-5000. **Circle No. 196**

MINIATURE RECORDER CHARTS WIDE RANGE OF AC V AND A. Model 400A uses plug-in signal conditioners. Plug-in modules offer F.S. ranges from 0-10 to 0-500V or 0-1A to 0-1000A. Recording is on rectilinear-grid, pressure sensitive chart paper at 1 in./hr (1/8 to 3000 in. optional). Gulton Industries, Inc., E. Greenwich, RI 02818. Phone(401)884-6800. **Circle No. 197**

DIGITAL DELAY GENERATOR PROVIDES 10-NSEC RESOLUTION. Accurate, low-jitter time delays from 10 nsec to 10 msec, selectable in 10-nsec increments, are obtained with Model 7055. A standard option extends the delay to 1 sec with the same resolution. Delay time can be set with thumbwheel switches or is remotely programmable with BCD inputs. A 100-MHz crystal clock serves as the time base. $1725. Berkeley Nucleonics Corp., 1198 Tenth St., Nucleonics Berkeley, CA 94710. Phone(415)527-1121. **Circle No. 198**

VISUAL COMPARATOR HANDLES PC BOARDS TO 16×16 IN. In the comparator, a production-line circuit board and the "master" board are compared directly as side-by-side mirror images. A lighted area of each board is seen simultaneously on a lighted screen at 3.6× size. The image flows out of a center dividing line on the screen to allow the inspector to compare for an exact match of parts in full color. Movement of the matching images is electrically controlled. Metron Optics, Box 690, Solana Beach, CA 92075. Phone(714)755-4477. **Circle No. 199**

TIME-INTERVAL METER PROVIDES ULTRA-HIGH RESOLUTION. With the Model 8330 you can make single-shot time-interval measurements with 100 psec resolution and do time-interval averaging with 100 femtosec resolution (along with period and period-average measurements to the same resolution). Full remote programmability and parallel BCD output are standard. Front-panel controls are single point programmed, and trigger levels utilize BCD 4-bit code. $5500. United Systems Corp., 918 Woodley Rd., Dayton, OH 45403. Phone(513)254-6251. **Circle No. 200**

OVERLOAD PROTECTED 3-OUTPUT BENCH SUPPLY SERVES DC NEEDS. Model 6236A delivers 0 to 6V at up to 2.5A and tracking plus and minus outputs from 0 to 20V, each at 0.5A (tracking is within 1%). Regulation is 0.01% +2 mV, with ripple and noise of 0.35 mV rms/1.5 mV p-p. The supply can be powered from a nominal 100, 120, 220 or 240V, 47-63 Hz input. Current-limiting circuits protect all 3 outputs. $325. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304. Phone(415)493-1501. **Circle No. 201**

WIDE-RANGE DMM FITS TODAY'S DC MEASUREMENT NEEDS. Model 160B provides voltage sensitivity from 1 μV/digit to 1200V, current-measuring capability of 10 pA/digit to 2A and resistance capability of 1 mΩ/digit to 2000 MΩ. Battery operation (an option) does not impair any of the instrument's specs. Also, BCD digital output is offered as an option. All dc voltage ranges have $10^7 \Omega$ input impedance. $525. Keithley Instruments, Inc., 28775 Aurora Rd., Cleveland, OH 44139. Phone(216)248-0400.

Circle No. 202

IC TESTER MEASURES DC PARAMETERS OVER EXTENDED RANGE. The Model 5570 automatically measures voltages to ±80V and currents from ±40 nA to ±500 mA. It has stored program operation and control for all data-sheet dc characteristics. The tester is available with interface for use with XINCOM's 7710 computer system. Measuring only 20×26×26 in. and weighing 100 lbs., it conserves space. $25,000. Xincom Corp., 8944 Mason Ave., Chatsworth, CA 91311. Phone(213)341-5040. **Circle No. 203**

COMPRESSION/EXPANSION SYSTEM HANDLES 100-dB SIGNAL RANGES. Model 3170, designed to interface wide dynamic-range input signals to a standard instrumentation tape recorder, puts the compressed signals on magnetic tape. They may then be analyzed using conventional spectrum-analysis equipment, or restored to their original dynamic range prior to analysis. A built-in calibration generator compensates for tape-recorder gain and offset errors. Ithaco, Inc., 735 W. Clinton St., Ithaca, NY 14850. Phone(607)272-7640.

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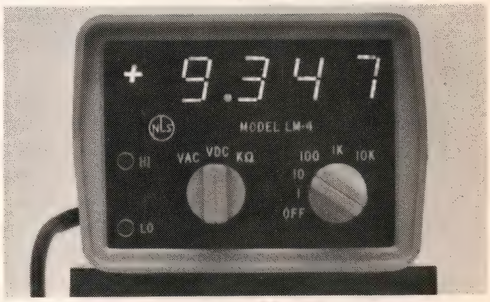

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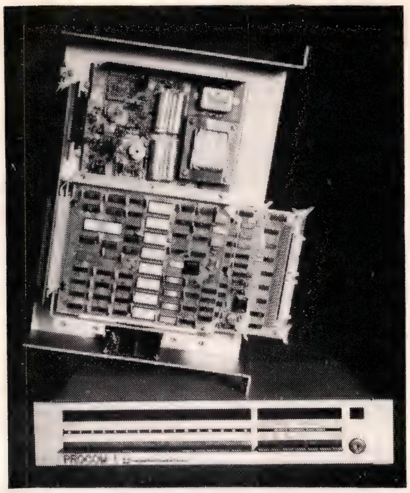
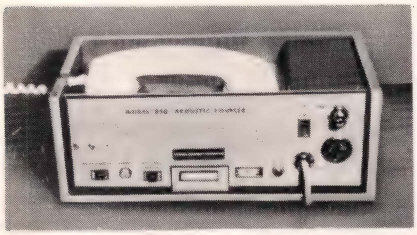


MICROCOMPUTER MASQUERADES AS 'SMART REMOTE'. PROCOM 1 is a hardware/firmware computer directed measurement and control system. Two asynchronous serial parts accommodate the EIA RS-232-C interface; one with standard modem signals and the other with 20-mA TTY current loop signals. The firmware, compatible with IBM 2260 line protocol, supports transmission rates up to 19.2k baud. The CPU is an 8-bit μP with 2k×8 pROM and 512×8 RAM memory. $2995. Computer Products, Inc., 1400 N.W. 70th St., Ft. Lauderdale, FL 33307. Phone(305)974-5500.

Circle No. 205

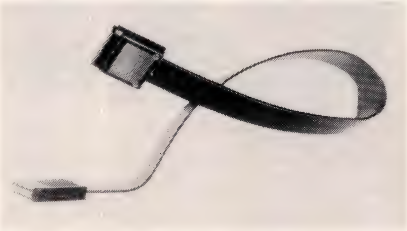


ACOUSTIC COUPLER OFFERS PLAIN OR FANCY PACKAGE. Packaged in a wood-grained cabinet or on a bare pc board, Model 920 has its own IC regulated power supply. Compatible with the Bell 103A modem, the unit can interface with any EIA RS-232 connector. Operation rate is 0 to 300 baud in full or half duplex mode. Data to acoustic operation switching is automatic. Standard features include a carrier detect light and direct access arrangement. $199.50 with case, $99.50 bare. Tycom Systems Corp., 26 Just Rd., Fairfield, NJ 07006. Phone(201)227-4141.

Circle No. 206

COMPACT, LIGHT-WEIGHT DIGITAL PRINTER OPERATES SILENTLY. Datalog model MC-5000^{R} is an 800 lpm, nonimpact printer that can operate from any digital source as a teleprinter and printer/plotter. It uses a 7×9 dot matrix to form a 128 char. ASCII set, but any code will be available on request. Weight is 30 lbs. with power supply in an 11×6×13-in. package. $6000. Litton Industries, 850 Third Ave., New York, NY 10022. Phone(212)752-7900.

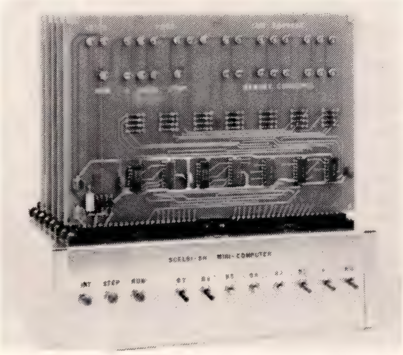
Circle No. 207



TRANSMISSION CABLE CONNECTS PERIPHERALS TO IBM 360/370. This flexible flat transmission line is compatible with the SLT pin field of IBM. It utilizes Ansley low-crosstalk BLACK MAGIC™ dual dielectric cable. Characteristic impedance is 93 ±5Ω. Far-end crosstalk is 1.5% max. when tested over a 10 ft. length driving 4 lines with a 5-nsec signal. $45 (100). Ansley Electronics Corp., 3208 Humboldt St., Los Angeles, CA 90031. Phone(213)223-2331.

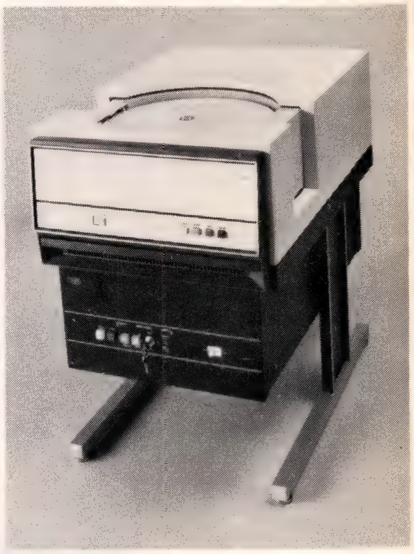
Circle No. 208

MODEM TRANSMITS OVER UNCONDITIONED DATA LINES. Model MCS9600, a 9600-bps modem, can multiplex mixed data rates. Internal noise filter design and equalizing techniques reduce signal distortion, and allow use of unconditioned type 3002 leased lines. The modem is easily integrated into point-to-point or multi-point data networks. $9700. Delivery is 30 days ARO. Intertel, 6 Vine Brook Park, Burlington, MA 01803. Phone(617)273-0950. **Circle No. 209**



DO-IT-YOURSELF MINICOMPUTER KIT SLASHES COSTS. Now you can construct a compact, light-weight, low-cost, medium-speed, digital minicomputer from a basic set of pc boards. The Scelbi-8H, a fully functional, general-purpose machine, will integrate with low-cost Scelbi peripheral interfaces. A wide range of software support is available. Assembled and tested card sets start at $440; chassis kits are $140; unpopulated card sets from $135. Scelbi Computer Consulting, Inc., Dept. H, 1322 Rear Boston Post Rd., Milford, CT 06460. Phone(203)874-1573.

Circle No. 210

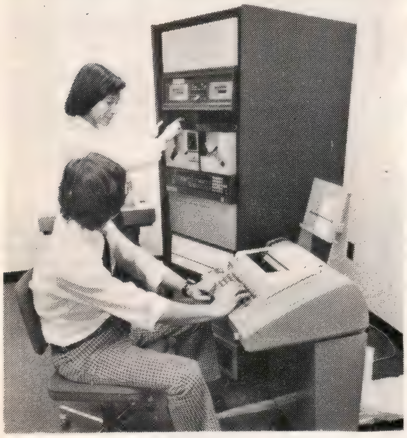


DISC DRIVE DELIVERS LARGE ON-LINE CAPACITY. At a cost of only 1/5¢/byte, Model 2260 Fixed/Removable Disc Drive provides full 10 M-bit storage. Total storage is divided equally between a pair of disc platters; one fixed, one removable. File maintenance is handled by either automatic file cataloguing or absolute sector addressing. Cyclic and longitudinal redundancy checksum tests are automatic on all reads. $16,500. Delivery 6-8 wks. Wang Laboratories, Inc., 836 North St., Tewksbury, MA 01876. Phone(617)851-4111.

Circle No. 211

PRINTER INCREASES CARD SYSTEM FLEXIBILITY. Operating at 100 char./sec, the 1070 data reporter adds line printing and reporting capabilities to card data recorders. Features include formatted reports from punched cards; automatic editing of card based reports; and preparation of mailing labels from punch-card files—all without the aid of a computer. Model 1 with 80 print positions costs $4180; Model 2, 132 print positions, $5550. Delivery, 90 days ARO. Decision Data Computer Corp., 100 Witmer Rd., Horsham, PA 19044. Phone(215)674-3300. **Circle No. 212**

HARD-COPY UNIT MERGES WITH GRAPHIC TERMINALS. Model 4631 is plug-to-plug compatible with all Tektronix 4010 series of computer graphic terminals and the 613 storage display unit. Using 3M Type 777 dry silver paper it requires 18 sec for the first copy and 8 sec for subsequent copies. The clean dry-copying process is self-contained with a built-in stacking tray. Weight is 65 lbs. $3895. Tektronix, Inc., Box 500, Beaverton, OR 97005. Phone(503)292-2611. **Circle No. 213**



32-BIT MINICOMPUTER ADDRESSES MEGABYTE MEMORY DIRECTLY. Model 7/32 features 16 32-bit general registers, 16 32-bit I/O registers, 192 instructions and full 32-bit logical and arithmetic manipulations. Up to 1024 auto driver channels are provided with automatic code conversion. Additionally, 1024 interrupt levels are offered, with a hardware-vectored service routine determining which device generated it. Priced under $11,000. Interdata of Canada, Ltd., 6486 Viscount Rd., Mississauga, Ontario, Canada. Phone(416)677-8990. **Circle No. 214**

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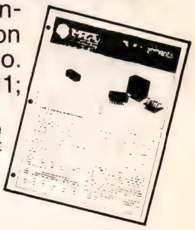

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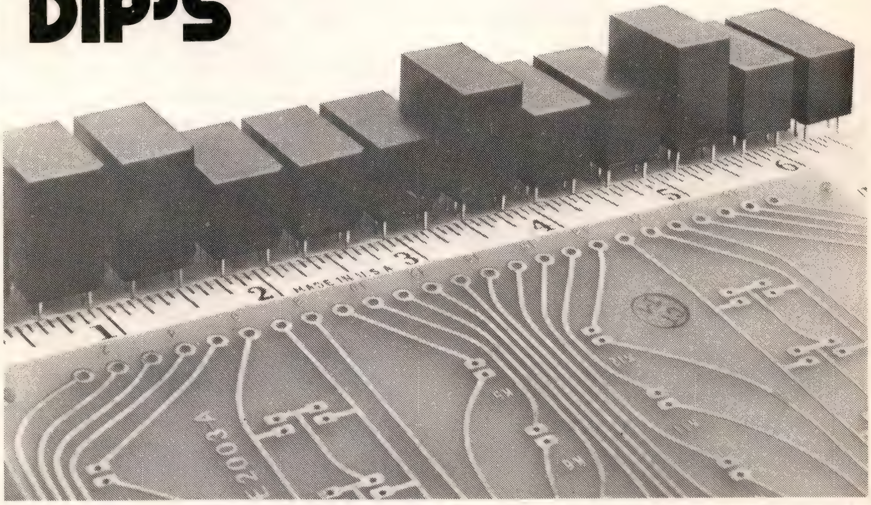

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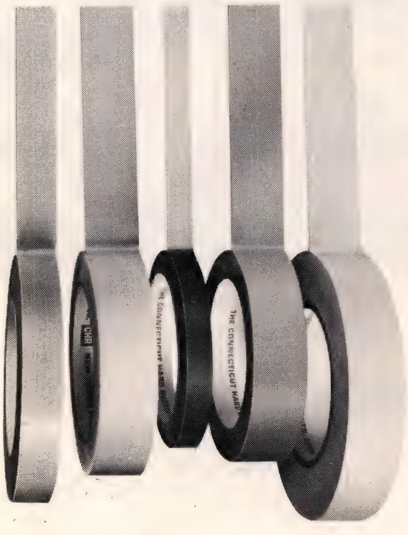

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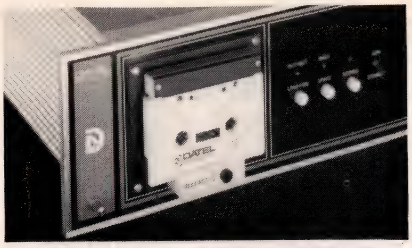
COMPUTER PRODUCTS



CASSETTE TAPE READER PROVIDES MULTI-INTERFACING. Model LPR-16 offers a full parallel minicomputer data bus interface and serial TTY RS-232-C interface. I/O loading can be bare TTL logic or optional pullup or pulldown resistors. Coding is customer programmed. Tape speed equals 2.75 ips with a density of 615 bpi. The unit will fit a standard 19-in. rack with 5-1/4 in. front-panel height. $2795. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. Phone(617)828-8000.

Circle No. 215

LOW-COST NOVA TAPE STORAGE BECOMES AVAILABLE. Offered in a variety of configurations, the Series 2400 is offered with 1 to 8 tape drives; each having 1-4 tracks. The storage medium is a 3M data cartridge that has an unformatted capacity of 720,000 bytes/track, or 2.88M bytes/cartridge. Data transfer is 6000 bytes/sec. $2550. Qantex, 200 Terminal Dr., Plainview, NY 11803. Phone(516)681-8350. **Circle No. 216**

MICROCOMPUTER MEETS CONTROL SYSTEM NEEDS. MicroPac 80 contains all hardware and software needed for implementing an industrial control system. Its hardware includes a full line of A/D and communications modules. Logic capabilities feature an 8-bit parallel μP with 78 instructions. The standard model includes teleprinter interfacing and TTL I/O. $2995. Delivery, 60-90 days ARO. Process Computer Systems, Inc., 5467 Hill 23 Dr., Flint, MI 48507. Phone(313)744-0225. **Circle No. 217**

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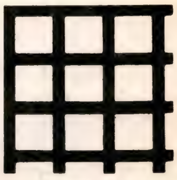
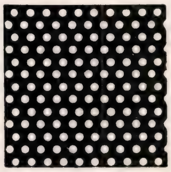
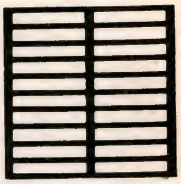


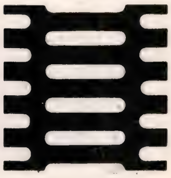
Square holes



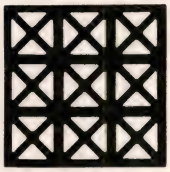
Round holes



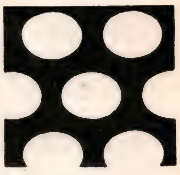
Slots



Oblong holes



Decorative patterns



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µP CALCULATES FAST FOURIER TRANSFORM. Providing integrated digital signal processing, this system performs computations of real-time freq. distributions, power spectrums, harmonic analyses or 1/3 octave filtering. Use of a µP simplifies signal conditioning and scaling. Offered are digitizing rates to 50,000 points/sec, input freq. range to over 3 kHz and quantization precision from 8 to 16 bits. Applied Systems Corp., 26401 Harper, St. Clair Shores, MI 48081. Phone(313)779-8700. **Circle No. 219**

A/D CONVERTER DOUBLES 6-BIT DATA RATE. The VHS-675 operates at any random or periodic word rate from dc through 75 MHz. Accuracy is 0.8% ±1/2 LSB. Specs include a 10 psec aperture, 80-MHz bandwidth and 500 V/µsec slew rate. Power supplies and built-in test words are part of the self-contained unit. $14,000. Delivery, 8-10 wks. ARO. Computer Labs, 1109 S. Chapman St., Greensboro, NC 27403. Phone(919)292-6427. **Circle No. 220**

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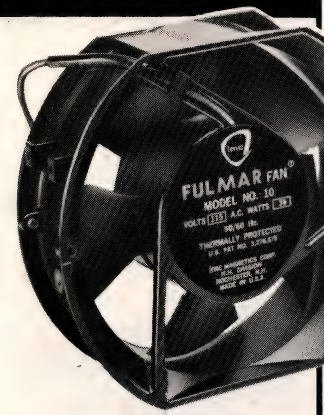

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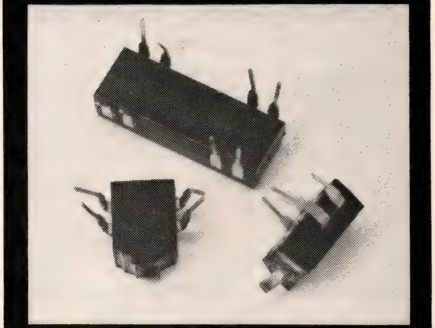

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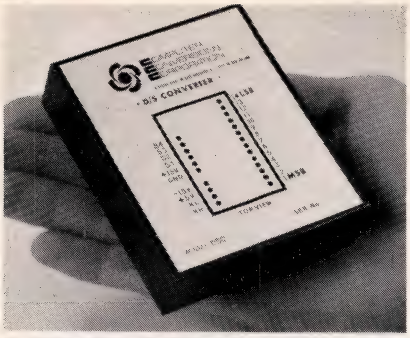
For more information, Circle No. 44



DIGITAL/SYNCHRO CONVERTERS CAN DRIVE TORQUE RECEIVERS. This series of small converter modules provides up to 3 VA power output and ±6′ accuracy when driving such a heavy load (size 11 TR). The units accept a 14-bit natural binary angle and convert it to 3-wire synchro or 4-wire resolver signal. Devices have short-circuit protected outputs and require only ±15V and +5V supplies. Standard output voltages are 90 or 11.8V rms l-l, 60 or 400 Hz. $450 (production qty). Computer Conversion Corp., 6 Dunton Ct., E. Northport, NY 11731. Phone(516)261-3300.

Circle No. 221

F/V CONVERTER SATISFIES GENERAL-PURPOSE APPLICATIONS. Model 4714's output voltage of 1 mV to +10V is a direct linear function of the 1 Hz to 10 kHz input frequency. It has 4 decades of dynamic range, and linearity of 0.08% of F.S. The output offset is guaranteed to be <±10 mV max. when the input freq. is zero. This offset can be externally trimmed for precision applications. $39.50. Teledyne Philbrick, Allied Dr., Dedham, MA 02026. Phone(617)329-1600.

Circle No. 222

DRIVER EASES INTERFACING OF DELAY LINES AND LOGIC. These TTL-compatible devices drive delay lines with characteristic impedances of 50 to 350Ω. With switch characteristics at full load, using a 50Ω 125-nsec delay line, rise time to logic "1" is 9 nsec, and fall time to logic "0" is 5 nsec. RCL Electronics, Inc., 700 S. 21st St., Irvington, NJ 07111. Phone(201)374-3311. **Circle No. 223**

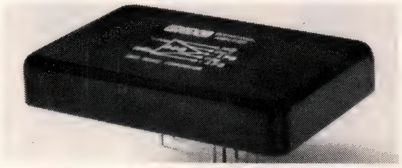
THIN-FILM CASCADABLE AMP FEATURES WIDE FREQUENCY RANGE. The WJ-A25 is a high performance, 5-1500 MHz amplifier designed to be used individually or in cascade. It offers 10-dB gain, 6-dB NF, +9-dBm power output and a third-order intercept point of +20 dBm. Internal power-supply decoupling, and stable dc biasing allow operation over the ambient temp. range of −54 to +100°C. The A25 is designed to be unconditionally stable for any source or load condition. $129. Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-4141.

Circle No. 224

5-BIT ADC PROVIDES HIGH SPEED OVER MIL TEMPERATURE RANGE. Model MSK520, a parallel converter on a single pc card, is comprised of an input buffer amplifier, high-speed hybrid comparators, Schottky TTL latches and decoders. The total throughput time is 50 nsec, allowing a 20 MHz update rate. Over the full temp range, drift is <±1 bit. Humidity, thermal shock and maintenance problems are overcome with open construction. M.S. Kennedy Corp., Pickard Dr., Syracuse, NY 13211. Phone(315)455-7077. **Circle No. 225**

DOUBLE-BALANCED MIXER SPANS BROAD FREQUENCY RANGE. Model WJ-M19 has a range of 2 to 14 GHz on the L and R ports, and 5 MHz to 4 GHz on the I port. A 2-tone intercept point of +20 dBm is typical with +13 dBm L.O. drive. This mixer offers flat IF response, typically ±0.5 dB for the full IF band, with a conversion loss of 6.5 dB over the full 2 to 14 GHz range. $490. Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-4141.

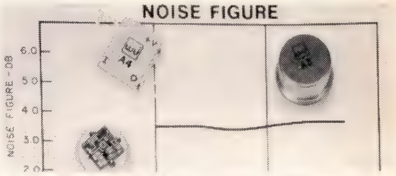
Circle No. 226



FOLLOWER SATISFIES HIGH VOLTAGE ISOLATION REQUIREMENTS. Model VF-666 will track 300V p-p signals from dc up through high frequencies with unity-gain accuracy of ±0.01%. Its input parameters (±1 mV of input offset voltage, 100 pA input bias current and input impedance of 10^{11}Ω), coupled with a slew rate of 50V/μsec, mark the VF-666 as an excellent means of supplying ±150V at 3 mA for a variety of applications. $250. ILC Data Device Corp., Airport International Plaza, Bohemia, NY 11716. Phone(516)567-5600.

Circle No. 227

POWER MODULES RETAIN RELIABILITY AT LOWER PRICE. The RN20 family provides 20A at various voltages between 4.5 and 13V dc. Line and load regulation are 0.1%, and ripple <0.02%. Standard features include short circuit and input-transient protection, and remote error sensing, Full-load operation at 71°C ambient does not require heat sinking or forced-air cooling. $249. Abbott Transistor Laboratories, Inc. 5200 W. Jefferson Blvd., Los Angeles, CA 90016. Phone(213)936-8185. **Circle No. 228**



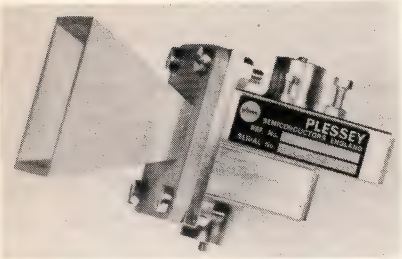
CASCADABLE AMPLIFIERS REDUCE SYSTEM NOISE FIGURES. The WJ-A3 (TO-8) and WJ-A4 (8-pin flatpack) have gains of 15.5 dB typ. and <1.3:1 VSWR over a 5-500 MHz bandwidth. They are designed for direct insertion into 50Ω microstrip RF and IF applications. Each model offers a noise figure of 3.5 dB typ. Both units are housed in hermetic packages. $109. Watkins-Johnson Co., 3333 Hillview Ave., Palo Alto, CA 94304. Phone(415)493-4141. **Circle No. 229**

DELAY LINE INCORPORATES OTC GLASS TO REDUCE DELAY DRIFT. Model CR02, an acoustic line, offers delay of 1.5 to 10 μsec, with a tolerance of ±5 nsec. Center frequency and bandwidth are 60 and 15 MHz, respectively. Specifications quote insertion loss of 23 dB max., and spurious signal level of −26 dB max. The device presents input and output impedances of 50Ω. Walther M. A. Andersen and Assoc., Inc., 4 Main St. Extension, Tariffville, CT 06081. Phone(203)658-7666.

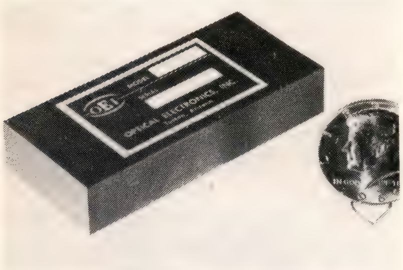
Circle No. 230

DC/DC CONVERTERS REDUCE SYSTEM GROUND LOOP PROBLEMS. The C5/T15/165X has an input of 5 ±0.5V dc, and 3 outputs: a 3-wire tracking ±15V at 165 mA and a +5V, 750 mA section with overvoltage protection. It features NL-FL reg. of ±0.02% and a temp. rise above ambient of 5°C/W dissipated. No heat sinking is required over the −25 to +71°C temp. range. $99. Stevens-Arnold, Inc., 7 Elkins St., South Boston, MA 02127. Phone(617)268-1170.

Circle No. 231



DOPPLER MODULE ENHANCES INTRUDER ALARM SENSITIVITY. Model GDM-3 uses separate transmitter and receiver cavities. The transmitter cavity is a Gunn-diode oscillator, while the receiver cavity is a mixer/receiver. Modules are available for freq. ranges of 8.8 to 9.9 GHz and 10.2 to 11.0 GHz, and can be supplied pretuned to any freq. within their range. Min. transmitter power output is 10 mW. With an antenna gain of 15 dB, the module has a detection range of 50 meters. $85 (100). Plessey Semiconductors, 1674 McGaw Ave., Santa Ana, CA 92705. Phone(714)540-9979. **Circle No. 232**



WIDEBAND AMPLIFIER SATISFIES VIDEO APPLICATION NEEDS. Model 9072 instrumentation amplifier provides the user with 10 MHz bandwidth and 250V/μsec slew rate. It has <1 μsec settling time at all gain levels. The unit is programmed for voltage gain by a single external resistor. It features a gain range of 0 to 100, and an output swing of ±10V at 200 mA load current. $165. Optical Electronics, Inc., Box 11140, Tucson, AZ 85734. Phone(602)624-8358. **Circle No. 233**

COMMUNICATION FILTERS HANDLE HIGH POWER. The HPF Series combines low-loss TE_{011} or TE_{211} mode design with low VSWR and minimal group-delay distortion. From 2 to 8-cavity selectivity is available, with in-line configuration standard (clustered configuration optional). Power handling in the passband is 4 kW, average. Units in the 4, 6, 11 and 13-GHz bands are among the standard parts in the series. Frequency Engineering Laboratories, Farmingdale, NJ 07727. Phone(201)938-9221. **Circle No. 234**

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Here's a new permanent magnet stepper motor line created to meet the design needs of analytical instrumentation and computer peripherals. Applications include tape drives, printer and chart drives and optical disc drives. Both 5 volt and 12 volt models are available.

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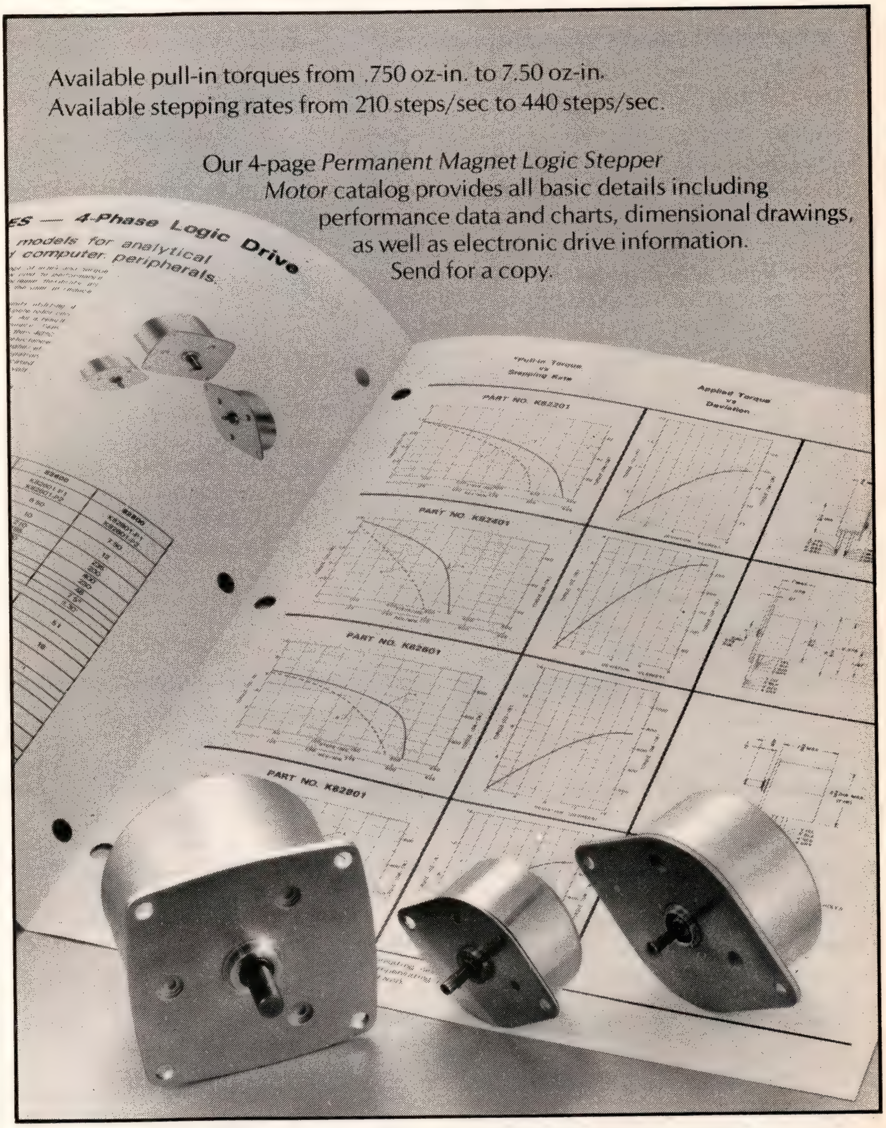
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LITERATURE

MULTIMETER. A 6-pg. brochure describes and gives complete specifications for a 4-1/2-digit lab-accuracy multimeter (Model 1450) that incorporates Tri-Phasic™ A/D conversion technique, Isopolar reference system and Ratiohmic™ resistance measuring. Data Precision Corp., Audubon Rd., Wakefield, MA 01880. **Circle No. 235**

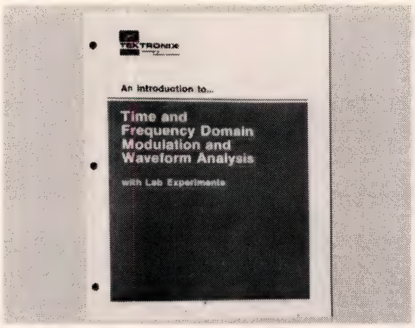
SIGNAL GENERATOR. App note, AN 171-2, tells how to extend the frequency range of the HP Model 8640A and 8640B downwards to dc (their standard range is 450 kHz to 1100 MHz). It shows how to build, with common stock parts, a simple external heterodyne circuit to do the job. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304.
Circle No. 236

SOLDER FLUX. A handy slide rule provides comprehensive flux selector data on one side and solder-alloy guides on its flip-side. Pocket-size, it gives flux choices for 22 metals and lists 36 solder alloys. Kester Solder, 4201 Wrightwood Ave., Chicago, IL 60639.
Circle No. 237

GUIDE TO DATA BASE SYSTEMS. Reprinted from the November supplement to DATAPRO 70, the report consists of detailed analyses of 6 widely used data base management systems. In addition, the report contains straightforward guidelines for selecting and implementing a DBMS. Datapro Research Corp., 1805 Underwood Blvd., Delran, NJ 08075. **Circle No. 238**

ADC'S. A 4-pg. data sheet describes the ADC-MA series low-cost general-purpose converters. These offer 10- and 12-bit resolutions using successive-approximation conversion techniques. All models feature multipurpose operation with 4 pin-selectable input-voltage ranges. The data sheet gives complete electrical, mechanical and environmental specs, along with calibration and applications information. Datel Systems, Inc., 1020 Turnpike St., Canton, MA 02021. **Circle No. 239**

SOS/CMOS GUIDE. This 12-pg. catalog of commercial and military IC devices covers hi-speed, low-power CMOS IC's, RAM's, multiplexers, SOS wafers and design kits. Inselek, 743 Alexander Rd., Princeton, NJ 08540. **Circle No. 240**



MODULATION. The 32-pg. booklet, "An Introduction to Time and Frequency Domain Modulation and Waveform Analysis with Lab Experiments," is intended to familiarize students with the most widely used types of modulation. Measurement techniques and instrument limitations are described in detail. Tektronix, Inc., Box 500A, Beaverton, OR 97077. **Circle No. 241**

DATA COMMUNICATIONS PLANNING. This 160-pg. guide to data communications planning, buying, implementation and applications is a combined tutorial handbook, applications casebook and industry directory. Special emphasis is placed on products, methods, and case histories. Ken Puleo Advertising, Mammoth Rd., Londonderry, NH 03053.
Circle No. 242

POWER SUPPLIES. A 24-pg. catalog describes over 70,000 combinations available in the standard product line. Products covered include both modular and rack-mounted units that offer constant voltage or current outputs with ac or dc inputs. Battery chargers, shielded line isolators and UPS units are also discussed. CEA, 1 Aerovista Park, San Luis Obispo, CA 93401.
Circle No. 243

VCO'S. A 24-pg. brochure compares basic types of microwave VCO's, and discusses critical parameters affecting their performance. Types covered include: fundamental-output transistor, Gunn-diode push-push transistor, low-noise and digitally-tuned. Frequency Sources, Inc., 166 Middlesex St., N. Chelmsford, MA 01863. **Circle No. 244**

MEMORY TESTER. A versatile, general-purpose test system for lab development and production testing of high-speed memory systems is described in Bulletin B-4603. The bulletin defines the basic elements of the system, presents a block diagram, and lists and describes operating modes. Specs and options are included. Technitrol, Inc., 1952 E. Allegheny Ave., Philadelphia, PA 19134.
Circle No. 245

ROTARY-DIAL CALCULATORS. Over 60 precision rotary-dial calculators share space in this 14-pg. catalog. Among them are units designed for the rapid solution of problems in engineering and design, inventory control, business, graphic arts and English-Metric conversions. Hunter Associates, 792 Partridge Dr., Somerville, NJ 08876. **Circle No. 246**

RESISTORS. Temperature-sensitive resistors with a large positive TC are described in the 4-pg. illustrated data folder, EPD TSR-5. Performance curves graphically illustrate the linear thermal response of these components. Electronic Products Div., Corning Glass Works, Corning, NY 14830.
Circle No. 247

CAD OF MICROWAVE CIRCUITS. Calculator Application Summary 5952-8924, entitled "Microwave Circuit Design with the HP 9820A & 9821A," describes a new software package, Microwave Pac Volume 1. Nine programs contained in the Pac are detailed, along with specific examples. Hewlett-Packard Co., 1501 Page Mill Rd., Palo Alto, CA 94304.
Circle No. 248

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A collection of the past year's Management Forum articles, written by Dr. T. F. Gautschi, P.E. and arranged into a management "coursebook" by the editors of Design News.

Ted Gautschi's Design Management Forum has been one of Design News' most successful new features. We have combined the past year's Forum articles into one reference-quality publication providing concise and up-to-date information on communicating, organizing and planning. Also contained are the full survey reports on ethics and management values; and articles on data processing, time management and the engineer's personality. As a bonus, we've added an article by one of Dr. Gautschi's university associates on the value of management training.

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RELIABILITY SERVICES. A brochure details a new concept in semiconductor and discrete-component prescreening and testing service. It describes the value of pre-conditioning and the thermal stress and test techniques used by the company and tells how "Reliability Service" can fulfill manufacturers' needs. Datatron, Inc., 1562 Reynolds Ave., Santa Ana, CA 92707.
Circle No. 249

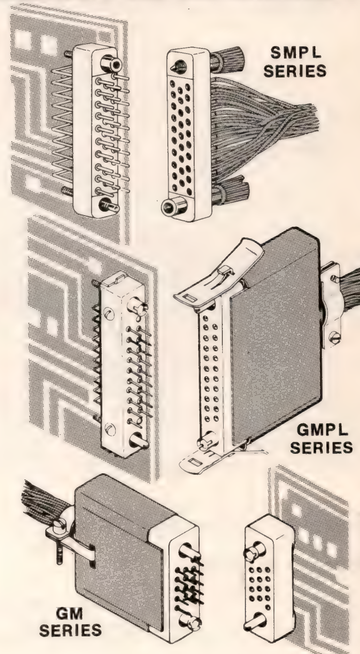
HYBRID POWER ASSEMBLIES. The 8-pg. brochure provides complete specs and ratings for the PACE/pak hybrid power assemblies. In addition to circuit diagrams, the literature contains 11 graphs, dimensioned outline drawings and photographs of the various devices. An example of how to apply the PACE/pak is also provided. Semiconductor Div., International Rectifier Corp., 233 Kansas St., El Segundo, CA 90245. **Circle No. 250**

SELF-PROGRAMMING ANALYZER. A 6-pg. brochure describes the features of the AutoTrak self-programming continuity test system for backplanes, harnesses and cables. Also included is a brief summary of the AutoTrak's various operating controls, error detection displays and models available. Addison Div., Muirhead, Inc., 1101 Bristol Rd., Mountainside, NJ 07092.
Circle No. 251

FHP MOTORS & GEARMOTORS. The 36-pg. catalog lists detailed rating tables, performance curves, specifications, application data, dimensioned drawings and ordering information. It also contains a unique Speed-Torque Horsepower Chart and engineering data on the application of FHP motors and gearmotors. Howard Industries, One North Dixie Hwy., Milford, IL 60953.
Circle No. 252

ELECTRONIC INSTRUMENTATION catalog combines both the DigiTec and Monsanto product lines in its 68-pgs. Divided for convenience, the book has sections on digital voltmeters, multimeters and panel meters; time and frequency measurement devices; calibration and signal sources; temperature measurement equipment; and data-acquisition systems and components. United Systems Corp., 918 Woodley Rd., Dayton, OH 45403. **Circle No. 253**

For A Choice of Printed Circuit Mountable Connectors
Miniature and Sub-Miniature



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Right angle or vertically mounted styles are offered as standard and provide an easy way to make direct cable connections to a P/C board or flexible circuit. Greater contact densities can also be achieved.

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For more information, Circle No. 46

signals and noise

Energy slogan contest has a winner

Quite some time has passed since the end of EDN's energy slogan contest. It seems that after seeing the 5000+ entries, the editor suffered an energy crisis himself. However, now that energy is back in the headlines, this is an appropriate time to name a winner and to list some of the better runners-up. We hope that these interesting and humorous slogans will help all of us remember that the energy problem is still with us. Let's all do our best to conserve.

The winning entry is:
"Fuels rush in where drivers peel the tread."

Congratulations to Mr. S. C. Kish of Mayfield Village, OH for coming up with this slogan.

Now here's some fine runners-up!

"Wasting energy is De-generating"

"You can't have your P=IE and consume it too!"

"Keep an eye on the family joules"

"You can't fuel an oil fool"

"Eat more beans—we need the gas"

(Road sign) "Damn the schedule, slow speed ahead"

"Make love—not KWHR"

"A young Shiek, Abdul by name,
Thought that black stuff was all the same.
'Till he applied some pressure by reducing the measure,
And now that's the name of the game."

"The oil, pumped out of the ground
Seemed unending, until we found
That a little bit less
Made a helluva mess,
And the lines stretch for blocks around."

"A fuel and his energy are soon parted"

"Our Current assets are reVolting"

"Less power to the people"

"Watt wasters are joule thieves"

"Save energy—sleep late"

"Public transportation prevents gas pains"

"Care enough to use the very least"

"Jesus saves—HE drives 55!"

"Rejoice, for it is written: 'many are cold by few are frozen'"

"Lower the standard of wasting"

"Saving electricity gives me gas"

"Never have so many been so fueled by so few"

"Mary had a little lamp
Its fluoresce as white as snow
But every watt that Mary spent
The lamp was slow to glow."

"Save energy—Streak slowly"

"Brownout:—Voltslagen!"

"Better less power now, than powerless later"

"Only kids have more energy than they need. Don't waste it!"

"Watts down, Doc!"

"He who lights a thrifty way will have some light another day"

"Dimmers are bright"

"Drive together—Thrive together"

"Don't fuel around—Pool around"

"Blessed are those with a tank of gas, for they shall inherit the road"

"He whose gas lasts gasses less"

"Save a watt in your OHM"

"Jesus saves, how about you?"

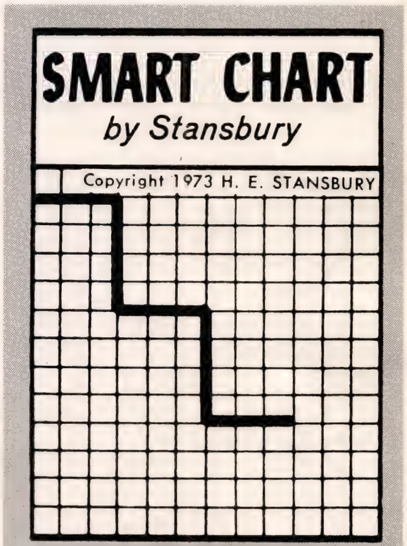
"Power shortages leave me cold"

"Close the generation gap—save electricity"

"The conserver sees his tank half full; the speeder, half empty. Save gas."

"Don't heat your home—invite a politician to dinner"

"Wasted energy can launch us into the Dark ages."



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Operation is as simple as selecting the function and signal connection. The measured value is displayed through the automatic selection of 5 functional modes: range selection, unit display, polarity, overrange indication and overload protection.

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Besides the AC power supply, the standard composition includes an alkaline battery. Optionally available is a rechargeable battery. Standard accessories include a battery charger.

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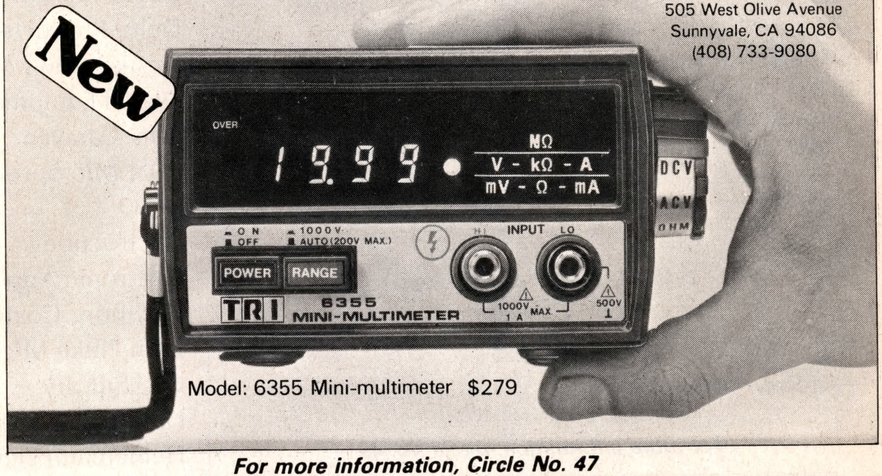

Model: 6355 Mini-multimeter $279

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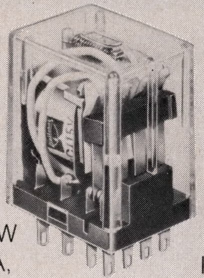

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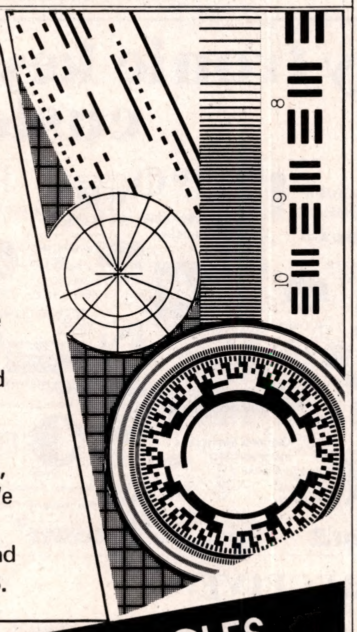

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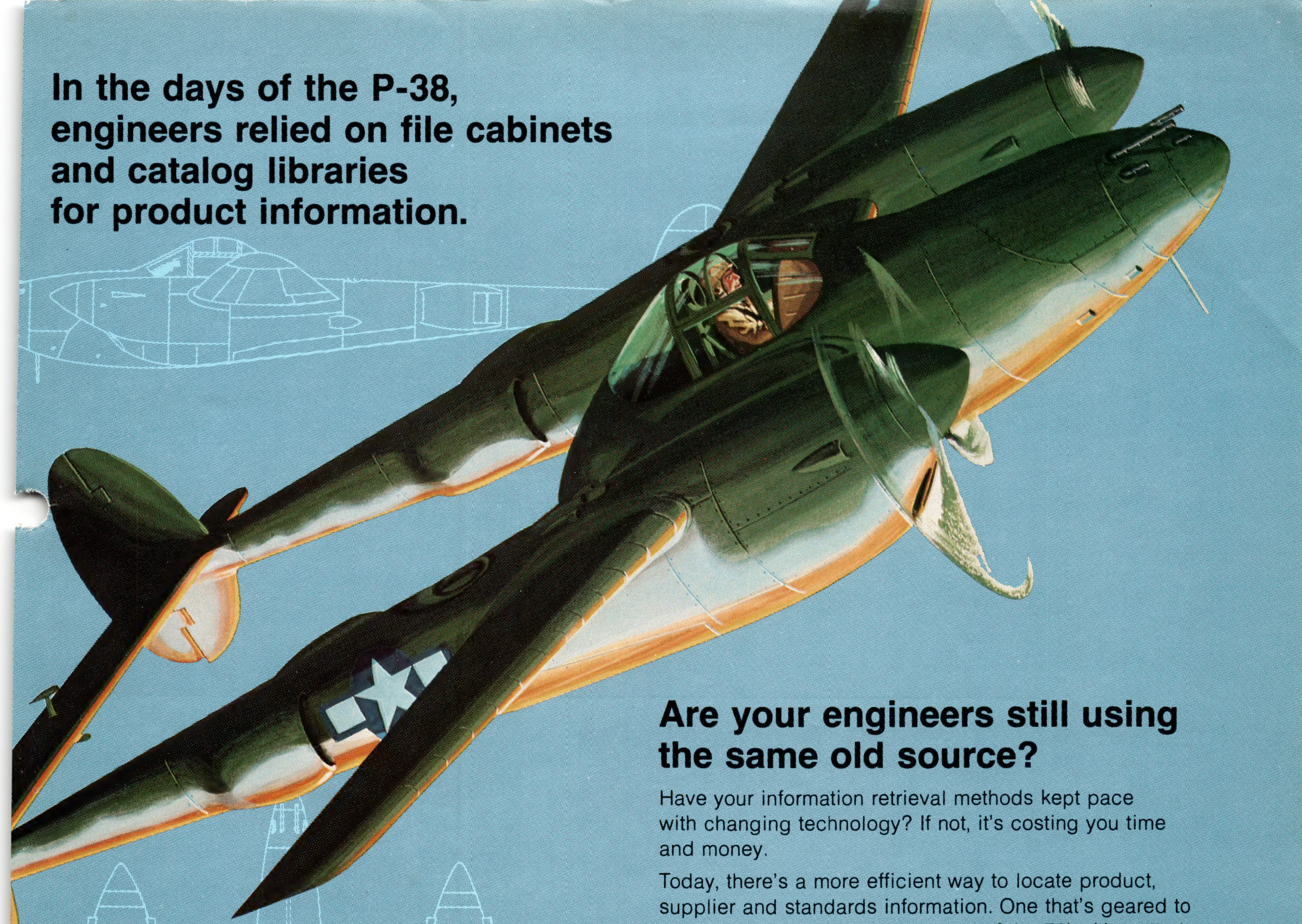

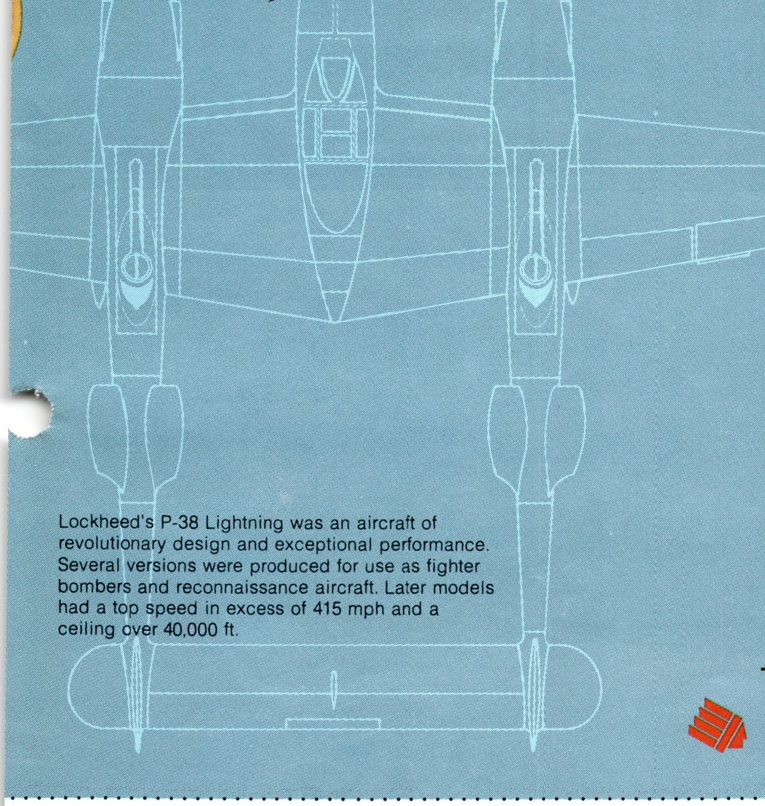

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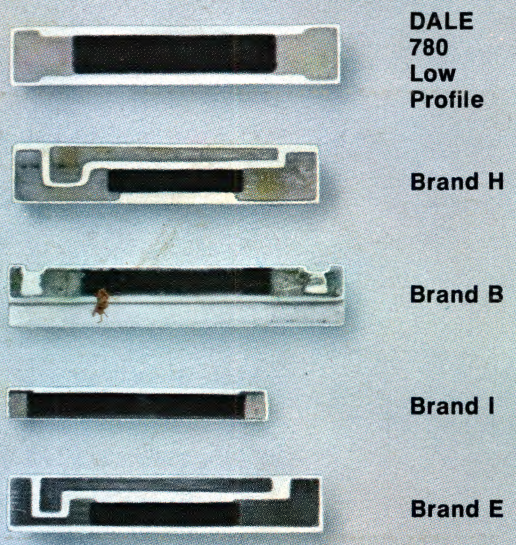

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